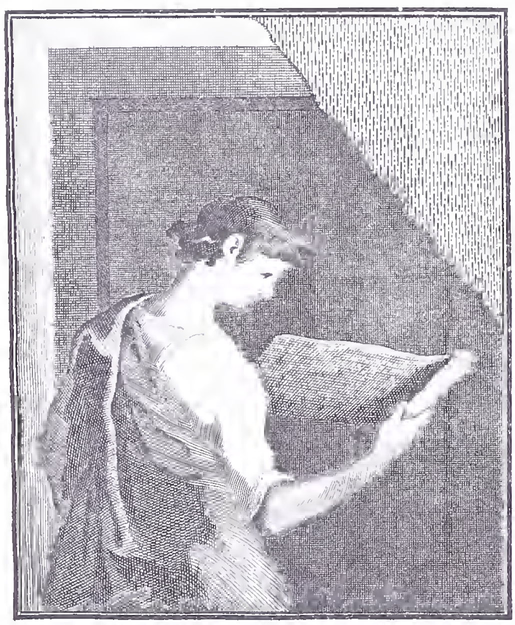

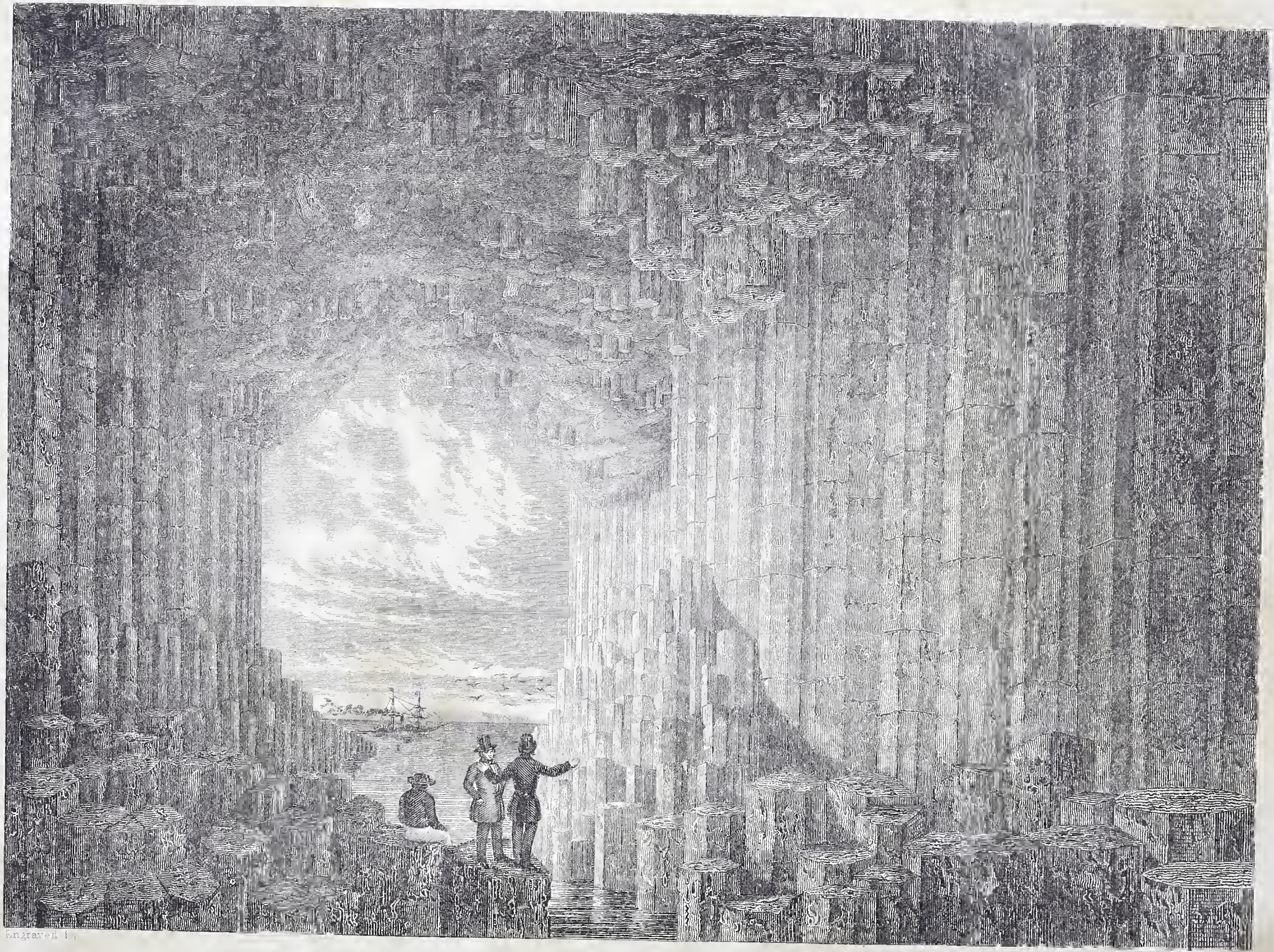

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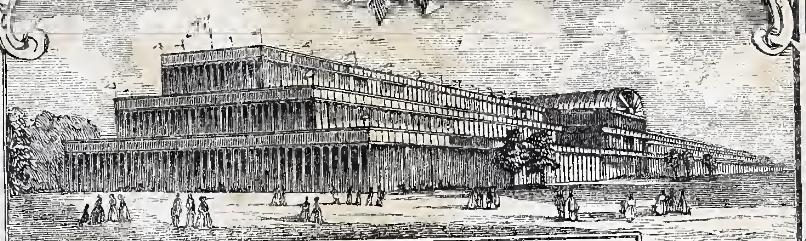


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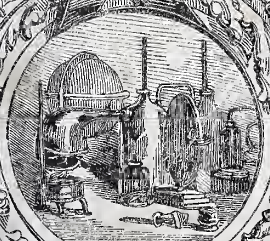
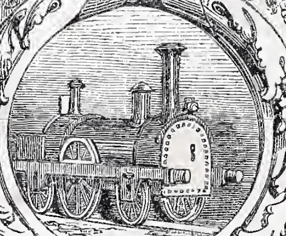
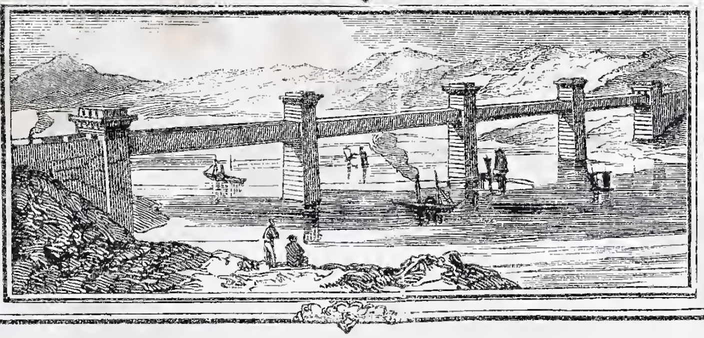

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THE

IMPERIAL JOURNAL

OF

ART, SCIENCE, MECHANICS, AND ENGINEERING.

ON THE IMPORTANCE OF EDUCATION AMONGST THE LABOURING CLASSES, AND THE ADVANTAGES DERIVED FROM OUR PUBLIC EDUCATIONAL INSTITUTIONS.

That it should be needful, at the present day, to point out the importance of education to the community at large, or to any particular class, is in itself a painful consideration. Such, however, being the case, it becomes our duty, instead of indulging in sentimentalities at the magnitude of the evil, to do what in us lies for its removal, or at least diminution. Stale, therefore, as such a theme may appear to some readers, and hopeless as may be the attempt to throw new light upon a subject so often examined by the greatest minds of the past and present, we shall not shrink from the task. There is no truth so palpable, so evident, but requires to be again and again urged upon the public through the most varied channels. The doctrines we seek to enforce may be plain as the sun at noon-day, but what the better if men's eyes are shut? So long as any portion of mankind remains in ignorance, and contented ignorance, so long we must call them to a sense of their danger, caring less for the novelty or originality of our arguments than for their utility. Those, therefore, who deem it tiresome to renew the discussion of truths so generally acknowledged, we would gently warn that for truths so generally acknowledged to remain unpractised, is more tiresome still. If our remarks should awaken a single mind only to a sense of the value of education, we shall not deem our labour lost.

Our attention will be turned chiefly to the mental condition of the labouring classes, both as forming the bulk of the nation, and because amongst them the want of education has been most widely and painfully felt. In making this statement, however, we by no means seek to brand them as more indifferent to knowledge than the rest of the community. To their common condition of ignorance, there are, especially in the much-abused manufacturing districts, many and splendid exceptions—men not only well versed in the science or literature of the day, but who have even, amidst the most unfavourable circumstances, and with no other motive than the pure love of truth, made valuable additions to the sum of human knowledge. We allude more particularly to this fact, because it warrants us in indulging the loftiest expectations for the future. The soil that spontaneously brings forth noble fruits, even though scantily, may well demand careful tillage. What might we not expect from the countrymen of Sturgeon, of Detrosier, of Hobson, were their latent powers brought out by proper culture? And although the majority of the working classes are undeniably rude and ignorant, we must remember that the opportunities for improvement within their reach have been, until lately, and in some districts still are, scanty in the extreme. If the means of instruction, when offered, are often but slowly embraced by the people, we may well ask whether the middle and upper classes, nay, even the professed votaries of learning, always make a faithful use of the far greater advantages falling to their share. He that is without sin amongst us, in this respect, let him cast the first stone. In fact, the evils of popular ignorance too often escape our notice from their very universality. The uneducated man, like one born blind, has no conception of the good that he foregoes; and the evils which he cannot but feel, he traces to every cause but the right one. Providence, government, his rich neighbours, or luck, must bear the blame when he suffers. He no more feels his own ignorance and its results, than do the inmates of a newly-painted house perceive the noxious vapour which is all the while filling their frames with poison. This is one of the great practical difficulties which meet us in dealing with the education question—that we must, as it were, plead the cause of men who do not own themselves aggrieved. Even the better-informed class of society have very little conception of the extent and dangers of popular ignorance. We have grown up amongst it; we have more or less breathed its polluted atmosphere; we have been taught, perhaps, to rank its consequences in our dastardly catalogue of necessary evils. We may glance over statistical returns which prove that so and so many per cent. of our Saxon coun-

trymen—the countrymen, be it here understood, of Bacon, of Shakspere, of Newton—are unable to read or to write; but we do not fully realize to ourselves the awful meaning of the words. Did we view them aright, they would be to us a vision of coming doom, a very handwriting on the wall. Did we view them aright, we should no longer oppose education, except it could be made to promote our individual influence, or the aggrandizement of our order, but should rise up as one man, and labour in union for the salvation of our common country.

In urging the claims of education upon the labouring classes, we are sometimes encountered with the question, "How much knowledge do they require? what do you consider a proper limit for their education?" A working man was once thought sufficiently instructed if he could repeat his catechism, and take off his hat to the 'squire; and anything beyond might have been judged uncalled-for, if not unsafe. Others would prescribe him an allowance of "reading, writing, and arithmetic," with perhaps a homœpathic dose of some science having direct reference to his occupation. But, if education implies the full and harmonious development of each and every faculty of mind or body, this, with all deference we would urge, is no education at all. Reading and writing, indispensable as they undoubtedly are, differ from knowledge, just as the key of a storehouse differs from its contents. Nay, be it remarked in passing, if we put such a key into the hands of the unthinking, without some further guidance, we must not be surprised if they occasionally find poison instead of food. We teach the labouring classes to read and write, deeming we have thus fulfilled all righteousness, and indulge in much virtuous indignation if they employ the one attainment in perusing penny garbage, and the other in decorating our walls with blasphemy; whilst our obstructive neighbours bray, "This comes of your boasted education!"

To return. The mind requires knowledge, just as the body calls for food, and the amount of neither depends on the rank and wealth of the individual. The rich may have greater facilities for gratifying the cravings of both, but the necessities of the poor are equally great. Whatever may be a man's station, he forms part of a universe whose laws he cannot break without suffering, and cannot observe without knowledge. He has a body with whose structure and functions he should be acquainted; a mind whose laws of action ought not to be strangers to him. The various processes by which we seek truth should be familiar to him. He has a mind open to all the charms of poetry and art. Milton has written, Beethoven composed, and Thorwaldsen chiselled for the operative as well as for the millionaire. Philosophy, like religion, is no respecter of persons. To the question, therefore, how much knowledge a working man should have, we would answer simply, "As much as he can possibly attain—the more the better for himself and for us all."

Perhaps the best method of pointing out the benefits of education to the labouring classes will be, to show the various evils which they suffer from its absence. Ignorance has been well likened to a "leaden sword, with which the masses are expected to fight the social battle;" or, again, to a "dark place, where poor people are allowed to grope about till they hurt themselves, or somebody else." If our notion of education be correct, the uneducated man is, in the highest sense of the word, no man at all. He is a being in whom the noblest parts of humanity have remained dormant, undeveloped, or have grown up into some distorted and unnatural shape.

We shall endeavour to trace how the want of education affects a man under different points of view. It involves him, firstly, in political degradation. If the working classes have long and earnestly demanded some share in enacting those laws which they are required to obey, they have not always remembered that their ignorance has proved a most formidable barrier. Not only those whose avowed mission is to "check the advent of democracy," but even their truest friends, may well pause at intrusting the political franchise to men ignorant of the laws, the constitution, the history of their country—ignorant likewise of the first facts in political economy, and sure to be led about by every noisy and unblushing impostor. The ignorance of the people has cooled their friends, and heated their enemies. "Shall those," asked the latter, "take a share in enacting laws who cannot read them when made?" A sarcasm hard to rebut. If the working classes consider themselves entitled to a voice in legislation, let them first and foremost wipe off this reproach from their brow. What was refused with scorn to the ignorant, will be granted with respect to the enlightened.

Not only does the ignorant man hold a humiliating position in the commonwealth, but he is the constant, and, we might almost say, lawful prey of impostors and quacks of all classes. The political swindler finds amongst the uneducated, believers in his most impossible promises, and laughs in his sleeve as he appropriates the earnings of his victims. The apostle of "incredible creeds," Mormonism and the like, steps in to share the plunder. The inventors of "life pills" hail in the uneducated classes their most munificent patrons—men ready to buy and swallow, and to ascribe to the inert or deleterious trash the cure of fancied ailments. Fortune-tellers and "planet-rulers," in spite of the law, and of the vaunted intelligence of "this our highly-favoured country," derive a handsome revenue, and sometimes even roll about in their carriages, at the expense of working men. Such is the necessary fate of the ignorant man: he is the general dupe of society; his purse and person at the disposal of the loudest liar who may cross his path. To convince any inquirer of the vast amount of ignorance among us, we need only point to certain advertisements which regularly adorn our periodical literature.

But not to speak of the frauds of others, the man of uncultivated mind imposes upon himself. Unable to trace occurrences to their causes, or to perceive the connection of events, whether he seeks to escape an evil, or to secure an advantage, he is constantly turning his efforts in the wrong direction. Like that animal, which, if struck with a stick, vents its anger on the senseless wood, instead of on the hand that guides it, he too overlooks whatever does not affect him immediately and directly, how important soever may be its influence. Government, he imagines, is answerable for all his misfortunes; and whilst clamouring for some "remedial measure" which shall better his condition, he neglects the easier and wiser task of helping himself, and, by precept and example, helping his order.

Ignorance, further, is unfavourable to health. Statistical returns, recently collected in France, show that the average duration of human life is higher, by from six to eight years, in the departments where education has become most general. The man who knows nothing of the structure of his own body, nothing of the nature of the air he breathes, and the food he consumes, is ever in danger of transgressing some of the most important conditions of life. What an amount of disease and mortality, and of consequent poverty and crime, is brought upon individuals and the public from ignorance of the laws of ventilation! The evils hence resulting, though by no means confined to the labouring classes, press most heavily upon them. It is estimated that, in London alone, 26,000 persons die annually, not in the common course of nature, but in consequence of ill-ventilated and dark apartments, pestilent graveyards, unwholesome water, and similar nuisances. Public opinion might enforce the removal of these evils, but as long as the majority are in their present state of ignorance, how is such an opinion to be expressed, or even formed? It is very true that men totally ignorant of physiology may enjoy sound health, and attain an advanced age, having incidentally complied with its laws, or having been placed in favourable circumstances; but such instances are rare. We must be guided, not by exceptional, but by average cases. Who would saunter on a quagmire by night, because a solitary traveller had crossed it dry-shod?

And how is it with the social standing of the uneducated man? Does he meet with respect from his associates, his neighbours, or his employers? No; he is an object of contempt to the unthinking, of pity to the wise, but of respect to none—whilst the man whose language and conduct indicate a cultivated mind, however humble his station, will meet with the involuntary homage of consideration and politeness, where his uneducated companion is treated with insult.

Education is likewise favourable to morality. The very acquisition of knowledge implies self-denial, patience, firmness of purpose, and, to a considerable extent at least, repression of the mere animal passions of our nature. Though it would be absurd to expect that all men should become philosophers, still, in a majority of the educated, intellectual pursuits will doubtless absorb a portion of the time and energy which might otherwise be devoted to sensuality and riot. To the uneducated, few if any amusements of an innocent and refined character are open, and their leisure is therefore almost of necessity devoted to pursuits of a disgraceful and injurious kind. To such persons many of the loftiest and most intense sources of pleasure are of necessity sealed. The beauties of natural scenery, so fruitful a source of delight to men whose ideas of sublimity and beauty have been properly unfolded, make upon them little more impression than upon the beasts of the field. Nature, we must bear in mind, is like a bank; we can only draw out of her what we have previously paid in by study and reflection. The beautiful in the outward world is only manifested to the beautiful within us. The writer has seen two men, buried in the perusal of a filthy sporting journal, on the summit of Castle Rig, near Keswick, and on one of the loveliest mornings that ever dawned over that earthly paradise. And if previous training is needed before we can feel the charms of natural scenery, much more is this the case as regards works of art, music, and poetry. On the ignorant man, the most beautiful passages in our glorious national literature fall lifeless. To him they appear but a medley of words he barely understands, of ideas he cannot realize, of allusions which go beyond the scope of his mental sight.

It would be almost an insult to the understanding of our readers, were we to attempt any formal proof that education renders a man more apt to get on in the world, and to better his outward condition. We may remark, however, that it is not merely specific training in those branches of knowledge on which his trade depends, that serves to promote the interests of the working man. General education, and the habits of thought and action which it involves, will render him more valuable to his employers, and will, in consequence, better his condition There prevailed, at one time, a prejudice that learning would make a man unfit for manual labour. But we are able to state, from the testimony of some of the most extensive employers, that this fear is no less practically unfounded than theoretically absurd. On the contrary, the educated workman is generally admitted to be more reasonable, consistent, steady, and trustworthy, than his ignorant companion. The following evidence, taken from the "Report to the Poor-law Commissioners on the Training of Pauper Children," 1841, bears so directly on the influence of education on the outward condition of the working classes, that we cannot refrain from inserting it. Albert Escher, of Zurich, employing about 1,500 hands of different nations, states—"As men of general usefulness, I prefer the Saxons, because they have had a very careful general education, which makes them fit to take up any employment to which they may be called. The Scotch get on much better on the continent than the English, which I ascribe to their better education, which renders it easy for them to adapt themselves to circumstances. The English are, in conduct, the most disorderly, debauched, and unruly, and least respectable and trustworthy, of any nation whom we have employed (and in so saying, I express the experience of every manufacturer on the continent with whom I have spoken, and especially of English manufacturers, who make the loudest complaints). These characteristics of depravity do not attach to the English workmen who have received education, but attach to the others in the degree in which they are in want of it. Refinement produced by education would be beneficial to workmen, for in the present state of manufactures, mental superiority, system, order, punctuality, and good conduct—qualities all developed by education—are becoming of the highest consequence. . . The uneducated English workmen were so disagreeable as lodgers, that they found it difficult to get lodgings, and were obliged to pay more for them. Some of the best description of English workmen—one of the most superior, to whom we gave £5 a week wages, had so ill-bred a family (he came from Oldham, where they are notorious for want of education), that his salary scarcely sufficed for his expenses—do not take so high a standing as foreign workmen who only receive £50 a year."

This piece of evidence, taken at random from a large mass of similar tendency, proves how essential is education even to the outward comfort of a working man, and that, without it, the best wages will be of little or no avail. So far we have surveyed the loss and injury which the operative sustains from the want of education in his in-

dividual capacity, and we have certainly found them great and manifold. To furnish instances in proof would be easy, did space allow. But if any one thinks we have over-coloured the picture, let him only open his eyes, and he will soon perceive that "the half has not been told him."

But this is not all. Let us now enlarge our view, and consider the ignorant man in the various social relations of husband, father, neighbour, citizen, and we shall behold results yet more alarming. In all these relations he will be exerting an influence for evil, of a negative, if not of a positive kind. His family are placed in a state of degradation, moral, intellectual, physical, and social. Withdrawn from every elevating and humanizing influence, they vegetate in a kind of savagery more hopeless and more deadly than that of the Fuegian or Samoyede, and unless some fortunate circumstance interpose, they have no alternative but to become a curse to themselves, an ulcer in the vitals of the commonwealth, and a disgrace to the very name of humanity. What man, gifted with the feelings of a man at all, can knowingly and wilfully expose those nearest and dearest to him to a doom so loathsome, so dreadful? And what man, it may be added, possessing the smallest share of practical common sense, can look on with indifference whilst evils of such magnitude welter and ferment at his very door? True benevolence and enlightened self-interest, here at least, coincide, and would that their united voice might be loud enough to wake some of us from the fever dreams of our fancied security! For ignorance, or its consequences, will find a level. Some possessions fall in value with diffusion; education, on the other hand, will only assume its full importance when it shall have become universal. Little does it profit me, for instance, that I know and obey the laws of health, if the ignorance or negligence of my neighbour generate a pestilence.

Not only fear should move the upper and middle classes to exertion in rescuing their poorer brethren from ignorance, but the hope of advantage. There are, in art and science, many unsolved problems of the highest importance to society; give us, then, more heads and hands to attempt them, and the chances of their accomplishment will be greatly increased. We cry shame on the man or the nation that allows lands to lie untilled, or mines unwrought, and justly; but what are lands and mines in comparison with uncultivated intellects? We never know how much we lose, even in the tangible form of hard cash, by allowing one single mind to remain undeveloped. Yonder man, lounging at the pot-house corner, might possibly, if rightly trained, have vanquished the cholera, the potato disease, or some other no less formidable evil. Once more, then, let every ignorant man strive earnestly to acquire education, and every educated man seek no less earnestly to aid him.

Whilst urging upon the labouring classes the importance of education, we have at times, I think, taken too low a standard. We have very frequently advised them to study those departments of science with which their occupation might be connected. In so far we did well, but we should also have gone farther, in spite of the sneers of a certain party. The anile wits of Albemarle Street have indulged, indeed, in much vapid mirth at the idea of "teaching miners astronomy and fishermen geology." But science is valuable, to use the expression of a most eminent philosopher, not merely in the way of *doctrine*, but of *method;* that is, in other words, not alone from the individual facts and general truths which it may communicate, but from the mental discipline which its study confers. The pursuit of truth in any question, the avoiding of error—in short, the whole conduct of the understanding in practical matters, can be learned only by practice, by example. In the different sciences, we see every logical process, every method which the mind can bring to bear upon any inquiry, worked out and exemplified. Thus, if we wish to make ourselves acquainted with the art of reasoning, properly so called, we study mathematics; if we would learn the legitimate use of hypotheses, and the nature of scientific explanation, we turn to astronomy. Physics and chemistry teach us the arts of observation and experiment. Physiology perfects us in the comparative method, the art of rightly arranging and classifying objects according to their most essential property. Now, all these are most important parts of education. To draw conclusions aright from facts rightly observed, is the continual business of life. Studies, therefore, which perfect us in this, or in any auxiliary process, must be useful, whether the facts of which they treat occur in our daily vocations or otherwise. For a miner to learn astronomy, is, therefore, after all, no such very ridiculous step. Every man should possess a clear and correct, even though scanty outline of the whole body of natural science—this outline being, of course, more and more filled up in matters with which he is more immediately concerned. A single science, however beautiful and valuable in itself, can neither be fully comprehended, nor rightly applied to the wants of society, except viewed in connection with that grand whole from which it derives its principle of life, and in which alone it can be truly fruitful. But whilst thus insisting upon the study of science as the one and only means for attaining full intellectual discipline, we must not forget the emotional phase of our nature. To the bulk of mankind, in whom speculative activity does not predominate, literature and art will offer greater charms than science, and this tendency we would not seek to combat, knowing that our duty is not to thwart, but to develop nature.

Such, then, is the general outline of education we would propose as necessary for the labouring classes, no less than for all others.

If, however, we had nothing more to add, it would have been better to remain altogether silent. To point out the evils of ignorance, and to sketch the kind of education suitable for the people, would be a barren task, unless we could also indicate some means of escaping the one and securing the other. And this, fortunately, is not impracticable. A "royal road" to education, indeed, we cannot offer. Mental cultivation, under whatever circumstances, cannot be reached without persevering industry, nor do we, all points considered, think it desirable that it should. Knowledge earned without labour is never rightly digested and assimilated to our nature. The two great questions which bear on the education of the working classes, relate to *time* and *means.* In the first place, it is clear, that so long as the bulk of our population have to earn their own livelihood, no matter how complete a system of national education be introduced, and whatever improvements take place in our industrial arrangements, it will be impossible for them to complete their education at school. If we reflect, indeed,

that certain faculties are only developed at a comparatively late period, we shall at once admit the impossibility of completing a system of education which shall embrace the entire man, by the fourteenth or fifteenth year. It has even been remarked, that, in most persons, real education only begins on leaving school. Of course the unfinished work must be carried on at intervals of leisure. And we must here observe, that if any person's employment does not leave him time enough both for relaxation and for the full development of his inward being, there is something radically wrong in the circumstances in which he is placed. The man who lives merely to "get a living," whose whole time and energies are employed in providing for his bodily wants, might just as well not exist at all. He is like a machine, whose motive power is entirely absorbed by friction. But we believe that very few persons are thus situated. We are confirmed in this view by witnessing the many, from almost all sections of the working classes, who do contrive to find time for improvement, showing that where the will is present the way is not wanting. Meantime we hail every change which shortens the hours of bodily toil, and thus gives space for the purposes of the inward man. As regards the funds needed for the work of education, there is little difficulty. Apparatus, models, books, are certainly indispensable; and in spite of all that has been effected in the way of cheap literature (to which we shall refer below), it must be owned that books of standard merit are mostly high-priced. Generally, too, the student will need, at least at the outset, the aid of teachers and lecturers. But all these requisites, though demanding an outlay beyond the reach of individuals, are easily compassed by the principle of association. And if we leave, for a moment, lesser distinctions and questions of names out of sight, every such association is a Mechanics' Institution. Such institutions form, as far as we are aware, the only means by which scientific knowledge can be acquired by the working classes, and, indeed, by all whose life is not expressly devoted to study. As such, their resources, and the advantages which they offer, demand our earnest consideration. There can be no occasion that we should here describe for what purpose these institutions were originally founded, nor how the gradual expansion of their objects has rendered their name somewhat improper. Nor can we here narrate the opposition which they have encountered from parties jealous of the spread of education, nor the attempts now made in some quarters to supersede or rival them, by educational establishments "in connection," as it is termed, with some religious denomination, political party, benefit society, or trade. Yet we cannot but consider all such rival institutions as eminently injudicious in their very conception. Why should we introduce foreign divisions into a subject which has none of its own? Why cannot the friends of scientific and literary education, merge, for the time being, their differences on other matters?

To return to our more immediate subject, Mechanics' Institutions have been founded in almost every town and large village in the kingdom, and have met with considerable success, though not to the extent which their importance demands. We hear it often remarked, that they are ill attended by that class for whose benefit they were mainly designed—that they have become, too often, mere literary lounges, instead of places of serious study for the working man. If this is the case, where lies the fault? The charge, however, is by no means universally correct. In the Droylsden Institution, for instance, at least ninety per cent. of the members have always belonged to the working classes. In many places, we admit, the reverse proportion would be found to hold good. The writer has always made a point of ascertaining the state of the institution in any town or village he might chance to visit, and for this purpose has made it the subject of conversation with any of the inhabitants into whose company he has been thrown. He has found many persons bitterly and irrationally hostile to these institutions; multitudes ignorant of their nature and tendency, and consequently indifferent to their success; and not a few, especially of the working classes, *unacquainted with the very existence* of old-established and actively-conducted institutions. This is a startling, almost an incredible fact, over which we might ponder with little satisfaction. But instead of inquiring, with some bitterness, whether a dog race, a fat pig show, or a pigeon shooting match, would thus long have escaped the knowledge of the operatives, let us rather ask how this ignorance, this apathy, may best be combated. Now, it would seem that our policy in the management of institutions has not been sufficiently aggressive. We have deemed it enough to stock a library and news-room, to organize classes, and announce lectures, giving a certain amount of publicity to our proceedings by means of the press and the platform, and then sit with open doors, waiting for the ignorant to come forward and avail themselves of the opportunities for improvement thus placed at their disposal. Why, notwithstanding men are in general pretty well alive to their bodily wants, there is not a tailor or a grocer in town who does not take four times the pains to make his wares known to the public. And if such measures are necessary in matters of trade, where the demand has to create the supply, how much more in intellectual affairs, where the supply must often create the demand—where the ignorant man must first be laboriously brought to a sense of his ignorance, before we can expect him to take steps for its removal! Surely, amongst the philanthropic portion of the middle and upper classes, individuals might be found willing to employ a portion of their leisure in visiting the uneducated, and in a plain and friendly manner seek to convince them of the dangers of ignorance, and the importance of seeking after education. Or, if such a method be too troublesome, a few brief tracts bearing on the subject should be prepared for distribution. Every institution, in short, should have a recruiting service, a regularly organized propaganda, without which complete success is impossible. In some institutions, the absence of working men may be owing to that jealousy so apt to spring up among persons of different ranks and occupations when thrown into close contact, and in which both parties are often alike to blame. It is unfortunately very rare to see employer and employed able to stand side by side in any undertaking, without mutual coldness and distrust. We too often forget, that in an institution, as in a place of worship, all the ordinary distinctions of rank and wealth should be laid aside. Working men are especially jealous of an institution where their employers form the directing body. This explains the almost universal failure of literary institutions, reading-rooms, &c., established by benevolent and public-spirited mill-owners for the good of their hands. Malcontents are never want-

ing who insinuate that the whole affair is got up to cover some interested project, some inroad upon their rights; and even where no direct suspicion exists, the men, as they express it, can never "feel at home" in an institution, the property of their employer. It would be therefore desirable that the government of institutions, wherever practicable, should be intrusted to scientific and literary characters, medical men, or others who, from their position, stand neutral in those unhappy contests between employers and employed which so often embroil our large towns, and who might, therefore, gain and preserve the confidence of both parties. If, however, it proves anywhere impossible for the middle and working classes to attend one and the same institution in a kindly and fraternal spirit, there is only one step remaining—to open a new institution, distinguished by its charges, in order that no part of the population may be left unprovided. Thus in many towns there is an "Athenæum," or "Literary Institution," attended principally by tradesmen, commercial assistants, &c., and a "Mechanics' Institution" for the use of the working classes. In some instances, this subdivision of the educational field has to be carried still further. Beyond the necessary loss of numerical strength, however, this plan is attended with no evil results; the different institutions, governed by the same general principles, but adapted for different ranks in society, remain on friendly terms, and are usually ready to act in concert whenever it may be needful.

The scanty attendance of operatives, and indeed of all others, is sometimes due to remiss management. From the comparative feebleness of the speculative faculties in the majority of mankind, an institution has a much more delicate constitution, if we may so term it, than a commercial or a religious association. Nothing but eminently bad policy will ruin the latter, nothing but eminently good policy can maintain the former. To create a powerful *esprit de corps* in the institution, is, according to the writer's experience, the surest road to success, and where a majority of the members consist of young men this will rarely be found impracticable.

The nature of the lectures delivered in Mechanics' Institutions has not been in general calculated to instil into the working classes any warm interest for science. There has been, for the most part, too much of petty detail, of dry technicalities. These, on the contrary, should be left for private study, where alone they can be properly handled. In a lecture, where our aim is rather to excite curiosity, and point the way to research, than to impart minute instruction, we should give results rather than details. We should bring forward those lofty and extensive generalities, which, whilst they awaken thought, kindle also the imagination. We should frequently direct attention to the important part which science has played in the education of the human race—in elevating its ideas, freeing it from superstition and error, and enlarging its resources, and indicate its probable influence in coming ages upon the destinies of mankind. Biographies of scientific men, more especially such as have suffered persecution or neglect, or whose ideas have met with prejudice and opposition, and commemorative discourses in honour of important discoveries and inventions, will be found generally attractive. Wherever such a course is taken, the writer's own experience warrants him in asserting, that the working classes will soon view science not with contempt and indifference, but with a regard almost enthusiastic. We are also of opinion, strange as it may seem to many, that in the ordinary course of institutional lectures, too much attention has been paid to what is immediately practical. Technilogical dissertations on iron girders, railway carriage axles, tubular bridges, and the like, can interest only those professionally engaged in such affairs. That neglect of all speculation, not at once applicable to the wants of daily life, so common amongst us, is a most short-sighted policy, and is gradually enabling our French and German neighbours to steal a march upon us. It is all very well to be "applying" scientific principles already known, but unless we pry into nature for new truths, new principles, we shall soon find our stock exhausted. It is all very well to refine and work up the gold of science, but we must not neglect to visit the "diggins" for a fresh supply. It has been well said, reversing the vulgar (oh! how vulgar!) adage, that an ounce of correct theory is worth a ton of mere practice, since the former, like a seed thrown into the ground, springs up and bears fruit abundantly. No man ever did anything valuable in this world without having a theory in his head, whether he could utter it in words or not. Had he been properly educated, he would have been able to state his theory for the benefit and guidance of his successors. Our great master, Bacon, much as he insists upon the practical value of science, warns us again and again to beware of that blind utilitarianism which would bid us turn aside from abstract research. "Principles rightly discovered," says he, "draw after them whole squadrons of applications." No departments of science, we may here remark, are more generally popular in Mechanics' Institutions than chemistry, and the higher branches of physics, such as electricity and magnetism. Almost wherever a laboratory has been opened, it has been numerously and regularly attended. This is a most fortunate circumstance, since it is to the above sciences that we must chiefly now look for an augmentation of man's command over the external world. Infinitely wider and richer than mechanics, they have the additional advantage of being comparatively a virgin soil, of whose undeveloped resources we can scarcely as yet form any adequate conception.

But although the working of these institutions may, in one or other point of view, leave much to be desired, and though they may have frequently failed in reaching the class most in need of their services, and for whom they were originally designed, it must be owned that they have done very much for the diffusion (and something perhaps for the extension) of science and literature. According to Dr. Hudson's "History of Adult Education," the aggregate number of members was, in 1850, 120,081; the attendance at evening classes, 18,120; the number of books in the libraries, 815,516; the number of volumes issued, 2,026,095. These figures convince us that a great and valuable work is going on. If many of the members may acquire but a very scanty store of scientific knowledge, others, on the contrary, become sources of instruction to their families and associates. The yearly circulation of two million volumes cannot be without good effects, even when all due allowance is made for the demand for light reading. In order to illustrate various points already touched upon, we will take a brief survey of some of the Manchester institutions, which, in many respects, furnish good types of the whole class.

The Athenæum, which claims the highest standing, is now almost exclusively attended by the wealthier classes —merchants, manufacturers, wholesale tradesmen. From the first, it was never intended as an industrial school. Like most establishments of similar pretensions, its tendencies are rather literary than scientific. Refined amusement, social or intellectual, seems to be its object rather than severe study. Its valuable library, comprising upwards of 16,000 volumes, and its ample supply of current reviews and journals, afford, however, considerable advantages to the student. Perhaps, on the whole, it is more adapted to keep the educated (in as far as the bulk of the middle classes may be so styled) aware of all that is passing of interest in the world of science, literature, and the fine arts, than as an educational establishment, a place of study for the ignorant. Its classes, according to Dr. Hudson, have been almost uniformly a failure. Its "monster soirees," though unsuccessful in a pecuniary point of view, have, we believe, been indirectly beneficial to institutions throughout the country, by the great interest which they excited. Like many other institutions, it has been subject to frequent annoyance concerning local taxation. The statute exempting institutions from local rates, is, on one pretext or other, evaded in almost every instance. Possibly public opinion might be brought to bear upon the question; possibly poor-law guardians, and others who have been in the habit of thus harassing institutions with vexatious litigation, might be made to feel the paltriness (to use the mildest phrase) of their conduct.

The Mechanics' Institution, Cooper Street, founded in 1824, has a more educational character, and is more frequented by the working classes than the preceding. That it, however, does not entirely suit their wishes, appears from the fact, that out of an average of 1,184 members, 309 only were working men; and that of these, only 32 on an average belong to the most numerous class of operatives in Manchester, the mill-hands; and from the year 1835, these, too, seem to have been regularly on the decrease. This circumstance is the more to be regretted, as the absentee thousands are evidently not to be found giving their support to the minor institutions, such as the Ancoats Lyceum, or the Miles-Platting Institution. Whether the withdrawal of the mill-hands from Cooper Street be owing, as some suppose, to the high rate of subscription (5s. per quarter), or to their disinclination to associate with persons in what are considered higher ranks of life, we cannot here determine. We have found that the working classes often secede in consequence of measures carried by the influence of patrons and honorary members. We would particularly advise never to place even the smallest share of power in the hands of any individual not in the habit of constant attendance at the institution, and to have no merely titular officers. The evening classes at Cooper Street have been, in general, very numerously attended, and have evidently been productive of much good. The day classes for females have also proved a highly successful experiment. The lectures here, as in most institutions, have gradually assumed a lighter and less educational cast, aiming in many cases more at amusement than instruction. We have heard it maintained that lectures on different subjects are attended, not, as might be expected, by an entirely different audience, but more or less by the same. This proves that lectures are attended merely in order to pass the evening, rather than with the hope of gaining instruction. The weekly concerts have proved a failure in a pecuniary point of view, and thus the only argument in their favour, in our opinion, has fallen to the ground. The library contains upwards of 14,000 volumes, and the yearly issue exceeds 60,000. It will thus appear that very much has yet to be done, before any adequate provision for the mental wants of the people of Manchester can be said to exist. We believe, however, that Mechanics' Institutions will never be fully appreciated by the working classes, until the way has been paved by a comprehensive system of national education. These institutions are *colleges*, not *schools;* their function is to teach science and literature, not reading and writing, and hence we see them frequented mainly by such as have obtained the rudiments of learning elsewhere. What has been commenced at school, must be finished at the institute.

The "Young Men's Christian Association," as Dr. Hudson remarks, "arose from the hostility of the established clergy to the existing institutions of the town." Except in a somewhat more rigorous exclusion of amusements, in imposing a religious test upon its directors and members, and in the mixture of theological with secular instruction, it differs little from our regular institutions, nor are we aware that it escapes any of the practical difficulties which the latter have to encounter. Notwithstanding a very considerable amount of honorary subscriptions, the last report issued shows a balance against the "Association," whilst it is remarked, that "these accounts do not include the whole of the expenditure incurred." The Association offers the attractions of a news-room, classes, lectures, and social meetings.

We have yet to state some of the reasons which should induce the labouring classes to attend Mechanics' Institutions. These may be laid down in very small compass. Man requires, as we have seen, a higher and more comprehensive education than ordinary schools can supply, and, to the bulk of the community, Mechanics' Institutions offer the only available means for its acquisition. The advantages furnished by the institutions are very great in proportion to the subscription. For an annual outlay, varying from six to twenty shillings, the working man may thus command a well-selected library of perhaps thousands of volumes, and a news-room stored with reviews, magazines, and journals of every shade of opinion. If his home is unfitted for study, the institution offers him apartments, warm, light, comfortable, often elegant. Classes for various branches of knowledge, conducted by able teachers, await his pleasure. If he desires to hear a lecture, a Dawson, a Lewes, a Burritt, or an Emerson, is at hand to fill his mind with elevating conceptions. If he prefers amusements—amusements worthy of an intellectual being—these also are supplied. And, lastly, he shares the benefit of cultivated society; he finds comrades whose generous rivalry will inflame his zeal for science, and whose sympathy will cheer his onward progress. All this, too, he enjoys, not as the boon of grudging or ostentatious charity, but as his own by right. What would Roger Bacon, or Paracelsus, or, to come nearer our own times, what would Priestley, or Franklin, or the elder Herschel, have given in their earlier days for advantages such as many members of the Cooper Street Institution possess with indifference, and such as hundreds of young men reject as not worth possession? Truly, if the great thinkers of the

past could witness our apathy, our neglect, they would almost blush at having toiled and suffered for descendants so ungrateful. Surely the working men of England will not always put to shame the hopes of their best friends; surely they will reflect, that no political franchise can make those free whose minds are enslaved by ignorance. But it is not to the working classes alone that we would offer a pressing invitation on behalf of Mechanics' Institutions. Numbers of clerks, salesmen, and others of the mercantile class, though possessed of what is termed a good commercial education, are sadly in want of general knowledge, and, above all, have failed to acquire accurate and comprehensive habits of thought.

Free schools, generally supported by some endowment, are tolerably numerous in England, and might, under proper management, do much to lessen that want of elementary education amongst the working classes which so greatly cripples the progress of Mechanics' Institutions. Their internal arrangements vary greatly. In some, a specified number of boys not only obtain a gratuitous education, but on quitting the establishment each receives a certain sum as an apprenticeship fee. Others are industrial schools, each pupil being taught some manual occupation. From a variety of causes, however, these schools are much less useful than might be supposed. In many cases, where the property of such endowed schools has greatly risen in value, no corresponding increase has been made in the number of the scholars. In some instances, the masters, although receiving large emoluments, and occupying the premises of the foundation, have contrived to eject all pupils of the class originally intended, and to fill their places with the sons of the wealthier ranks, from whom they derive an additional revenue as boarders. We have heard an instance, where an assistant-master in a free school, receiving a nominal salary of £35, was able, after no very long period, to retire as an independent gentleman. The strange and absurd costumes prescribed for pupils in many of these establishments, are likewise an outrage upon all manly feeling. True charity would not, we think, insist upon labelling the objects of its bounty. In some parts, admission of a child to a free school is a kind of reward conferred on such of the working classes only, as have distinguished themselves by political or religious subserviency. But the kind of instruction given in these establishments is for the most part such—much as we lament the perversion of funds destined for the education of the people—as we do not greatly wish to see extended. The pupils do not learn to "state a proposition and prove it;" they are not made acquainted with their own bodily and mental constitution, with the law of causation, or with the general order of the universe around them. Nay, we even fear that, in some instances, principles unfavourable to mental refinement and civil liberty are insinuated into the minds of youth. There are, indeed, difficulties connected with endowed and chartered institutions, which, we believe, have nowhere been entirely avoided. On the one hand, they must be secure from all vexatious interference, whether on behalf of governments or of private individuals, and against all perversion from their original purpose. On the other, they must be made capable of advancing with the age, and not continue, in the 19th century, to offer an education fit only for the 16th. Neither can they be safely quite withdrawn from under the control of public opinion. Unless these two conditions can be reconciled, the age of endowments is past. We cannot afford to have educational establishments which, instead of being the guides of the nation, are a mere clog to its steps. At all events, our free schools, of every grade, should be rendered available for the whole English nation, instead of serving to uphold the pretensions of some particular party or order. We would earnestly exhort wealthy friends of education, instead of making bequests (which "two able Chancery lawyers," and a board of trustees, can apply in the most unheard-of manner), to extend their munificence, whilst living, to institutions whose nature they approve, and to trust for the future to the liberality of coming generations. The Cheetham Hospital at Manchester, which may serve as a specimen of our free schools, was originally destined for forty pupils; but the number has since been doubled. The period of education is from the age of six to that of fourteen, and the instruction received is not of a very high quality. The pupils, on leaving, are apprenticed at the expense of the school, and hence the number of applications for admission is often considerable.

Free public libraries are an interesting, and, in this country, a novel experiment. Here and there, indeed, there may have existed a collection of books, nominally open to the public; but either from their nature, the unsuitable hours of admission, or some vexatious regulation, all such have proved practically useless. The Cheetham Library at Manchester, and Stirling's Library in Glasgow, were, until within the last few years, the only exceptions. The former noble collection of 25,000 volumes has been all along freely open to the public; but from its retired position, and from its being open only during the hours mostly devoted to business, it escapes the notice even of the studious. The Salford Library and Museum, founded in 1849, has proved eminently successful, the attendance having increased so much, that, according to the last report issued, the committee are about enlarging the premises. It is remarked, "during the past year the readers and visitors have been far more numerous than in any previous year, and not only has the class of books read exhibited a growing preference for standard works, but the conduct of the readers has continued most exemplary." Of the readers, a very considerable proportion belong to the working classes. Even carters and boatmen are beginning to find the library more attractive than the adjacent taverns. To speak of the success of the Manchester Free Library might be premature, as it has only been ushered into being within the last few weeks. It differs from its contemporary across the Irwell, in containing, besides a library of reference of 16,000 volumes, a free lending department of 4,000. Any one may take out books from this department, on producing a certificate of trustworthiness, signed by two ratepayers. It is important, as a proof how much Manchester is alive to the value of education, that when the burgesses were polled on the question, whether the library should become public property, and be supported by a yearly rate, 4,000 voted for the measure, and only 40 against it. Free libraries will obviously afford the means of mental cultivation to a numerous class, whom Mechanics' Institutions have not been able to reach. It is, therefore, earnestly to be hoped, that the example of the "vanguard city" will be followed wherever practicable. Libraries will, we doubt not, prove a far better investment than jails and work

PHRENOLOGICAL CHART,

DESIGNED TO ILLUSTRATE THE TREATISE ON PHRENOLOGY,

In the "Imperial Journal of Arts, Science, Mechanics, and Engineering."

We have been at some trouble, as well as expense, in engraving the Symbolical Head here represented. The design originated with Mr. Fowler of New York, a Review of whose 'Phrenological Journal' appeared at the time in 'Goyder's Phrenological Almanac,' published in Glasgow, and its go-a-head tendencies were then very freely remarked upon. We have changed some of the symbols, but the main design is retained. We need not say, that many of the new organs introduced by Mr. Fowler are purely fanciful; at all events they are not sanctioned by the best-informed phrenologists. What Mr. Fowler may mean by the organ of "Human Nature," we are at a loss to conceive. We, however, subjoin a Key to the entire head, which will perhaps amuse our readers, while it exhibits the go-a-head tendencies of our Transatlantic cousins.

DEFINITION.

Phrenology is the science that treats of mind, explains its various powers, points out their harmony with each other, and shows the relation that exists between them and the external world.

THE BRAIN IS THE ORGAN OF THE MIND.

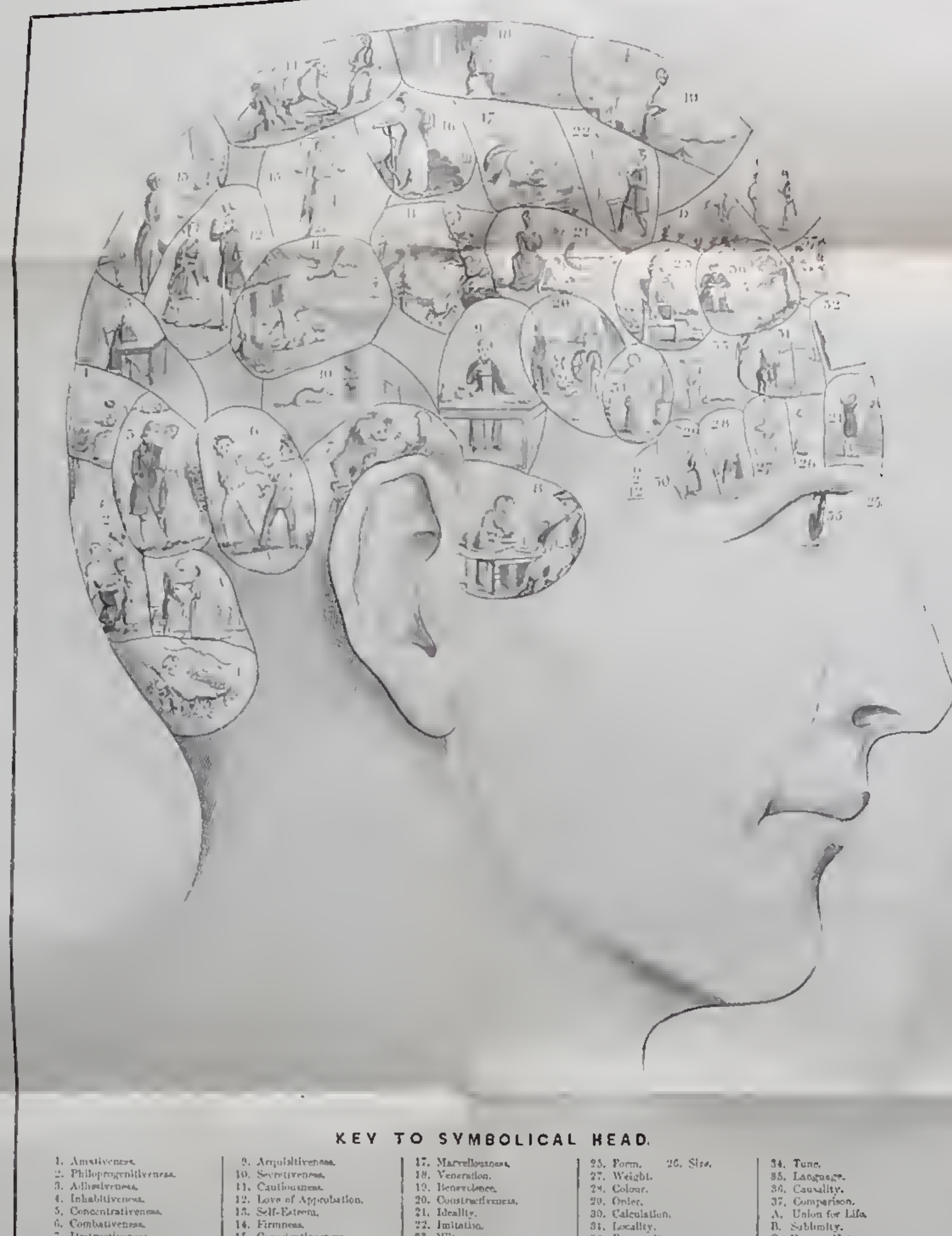
Animals which have no brain, do not seem to manifest instinct or mental power—vertebrated animals, from man down to the least perfect, manifest instinct, appetite, or mental power in a direct ratio to the quality and quantity of the brain which each possesses. Animals of the same species or variety, differ in mental manifestation: this difference arising from the size, the age, the health, or texture of the brain. The manifestation of the mental powers do not all appear at once and the same time, but follow in regular succession as the brain advances to complete development. In infancy, the brain is soft and watery—the manifestation of mind are then weak and volatile; in manhood, the texture of the brain is firm, and the convolutions close—the mind then is expressive of its fullest vigour; on the approach of old age, the convolutions separate, and the brain becomes shrivelled, and sinks within the cavity of the skull—then is the mind in its dotage, and its powers are manifested with feebleness and imbecility. If the brain becomes diseased, or suffers injury in one or more of its parts, the mind is also changed, and manifests a corresponding weakness in the part or parts affected. If, then, the state or condition of the brain affects the manifestations of the mind, the conclusion is justifiable, that the brain is the instrument through whose means the mind holds converse with external objects.

THE BRAIN IS AN ASSEMBLAGE OF ORGANS.

The brain is not a single viscus, but a congeries of organs, each of them the representative of a distinct and separate faculty of the mind. Animals which have the simplest form of brain, exhibit the most limited range of mental power; those, on the contrary, whose formation of brain is more complex, exhibit a more extensive variety; and man, whose brain is the most complex of all, manifests the widest range and the greatest variety of mental power. Individuals, whose brain consists chiefly of a lateral or posterior development, and are deficient of that part which gives a fulness to the forehead, are void of reason, and consequently classed in the scale of idiocy. Individuals whose greatest proportion of brain is behind the ear, are of a grovelling and sensual character; on the contrary, those whose development of brain is largest in front of the opening of the ear, are of an intellectual and amiable character. Melancthon was incapable of doing a mean and unworthy action. Pope Alexander VI. could not be otherwise than vicious: the former was decidedly moral and intellectual—the life of the latter was a series of the most infamous crimes. Among mankind, individuals manifest a great diversity of mind and variety of talent: one excels in sculpture, another in painting, a third in poetry, a fourth in music, &c. This could not be the case if the brain were not an assemblage of various organs. No course of educational training could transform the idiot into a philosopher, or make a poet of Pope Alexander VI. Talent is inherent—it is not the offspring of circumstances; genius is partial, and is found related only to a particular development of a particular organ of the brain. In dreaming, one or more of the organs of the brain are awake, while others sleep. If the brain were a single organ, it would be absolutely impossible for it to appear in such opposite states at one and the same time. If the brain were not an aggregate of parts, whence the monomania of insanity which often exists with the most acute intelligence, the other faculties remaining perfectly sane and active? If the brain were single, the whole mind would suffer. The brain is often called upon to perform at the same time different and opposing actions. In common life, we infer the character of others, not in accordance with their motives or feelings, but by a pro and con balance of our own mental lounges of those motives or feelings. In games of skill and stratagem we play a double part, and mentally form the schemes and movements of our adversary as well as of our own. Our self-communings and our waking dreams are the result of the activity of the opposing organs of the brain.

ORGANS OF THE BRAIN, HOW MANY.

That the powers of the mind are manifested through the medium of the brain, is now generally admitted; but all are not agreed with regard to the number of those powers: that they are numerous, is the theory of almost all the systems of mental philosophy. Phrenology carries the number as high as thirty-six, but conjectures there may be others not yet ascertained, as a number of convolutions are found in the base of the brain whose functions are not yet ascertained. There are also feelings in the mind to which no expressing organ has been assigned; but of the existence of which no one doubts: such are, personal identity, which gives the consciousness of existence; and love of life, which gives the desire to enjoy that existence.



KEY TO SYMBOLICAL HEAD.

1. Amativeness.	9. Acquisitiveness.	17. Marvellousness.	25. Form. 26. Size.	34. Tune.
2. Philoprogenitiveness.	10. Secretiveness.	18. Veneration.	27. Weight.	35. Language.
3. Adhesiveness.	11. Cautiousness.	19. Benevolence.	28. Colour.	36. Causality.
4. Inhabitiveness.	12. Love of Approbation.	20. Constructiveness.	29. Order.	37. Comparison.
5. Concentrativeness.	13. Self-Esteem.	21. Ideality.	30. Calculation.	A. Union for Life.
6. Combativeness.	14. Firmness.	22. Imitation.	31. Locality.	B. Sublimity.
7. Destructiveness.	15. Conscientiousness.	23. Wit.	32. Eventuality.	C. Human Nature.
8. Gustativeness.	16. Hope.	24. Individuality.	33. Time.	D. Agreeableness.

SIZE OF BRAIN IS AN INDEX OF POWER.

Size of brain as a whole, or of a single organ as a part (conditions being equal), is a measure of power, but does not express the activity of the brain, or any of its parts—the conditions of activity are as follow:—1st. The natural fineness of its texture; the brain, which is naturally of a fine and vigorous constitution, will manifest greater energy than another brain of the same size, but which does not possess the same natural quality. 2d. The general rule of power is also modified and influenced by a course of well-appointed educational training, which gives vigour to the organ so trained, upon the same principle that the frame is invigorated by frequent and well-applied exercise.

THE FORM OF THE SKULL REPRESENTS THE FIGURE OF THE BRAIN.

The brain with its integuments is first formed. The skull is a secondary formation, and accommodates itself to the precise form of the brain, as accurately as does the shell of an egg, or the rhind of an orange; the brain, consequently, fills exactly the cavity of the skull, and the integuments which are on the outside lie so close upon its surface, that the cranium may be taken, in every case, as a *fac simile* of the brain which it encloses; malformation, disease, or old age, produce exceptions—the sutures, which are the indented seams or joinings of the bones of the skull, and the frontal sinus, which is a cavity formed in the forehead, just above the nose, by the outer and inner plates or tables of the skull retiring from each other after the age of twelve years, and increasing as the individual advances to old age, also offer a slight obstacle. Though they do not interfere with the truth of the science, they render it a little more difficult to determine the exact size of the three or four small organs which lie immediately under them.

DIVISIONS OF THE BRAIN.

The brain is divided by the professional anatomist into the greater and lesser brain, in the middle of which a deep cleft or fissure is perceived, separating them into two halves or hemispheres; each half or hemisphere is again subdivided, though in a less marked degree, the divisions only being observed on its lower surface. These divisions are called the anterior, the middle, and posterior lobes, each occupying nearly one-third of the whole length of the brain. The lesser brain is situated immediately beneath the posterior lobe of the greater brain. But there is another division of the brain, not into lobes and compartments, but into powers or faculties; in this classical arrangement are grouped together those faculties that aid and assist each other, and whose organs are found located in juxtaposition to each other. For example, in the lateral and posterior parts of the brain, we have a range (including the supposed organs of personal identity and love of life, with alimentiveness) of all the powerful propensities which have, for their end and design, the consciousness, the enjoyment, the support, the continuance, the protection, and the defence of existence. These are the lowest passions of our nature, and are common to man and the lowest of the inferior creation. These organs embrace the numerical arrangement from 1 to 9 inclusive. The next class, from 9 to 12 inclusive, raises man in the scale of creation, and though common to the superior of the lower animals, yet carry with them the cause of sentiment. From 12 to 21 inclusive, we have the sentiments which are proper to man, and raise him high in the scale of created being. In this group are the three cardinal virtues, Faith, Hope, and Charity—in phrenological language, Wonder, Hope, and Benevolence. In this range also are to be found the organs of Justice, of Veneration, of Firmness, and of Ideality. These powers raise man to a splendid elevation in the scale of being, and in him, though dimly, reflect the attributes of the Author of his being. From 21 to 33 inclusive, we have the intellectual organs, through whose means we perceive the existence of external objects; they are called the knowing organs, because through their means we derive all the knowledge we possess; they are also termed the intellectual powers. The last division of the arrangement includes the two reflective faculties of Comparison and Causality; they are the most important of all the intellectual faculties, and preside over, and guide, and direct them: they constitute man a reasonable being. In this arrangement of the faculties, we discover the perfect hand of Nature herself, each group being assisted, and its power promoted, by the energy and activity of the other. This arrangement has not been, as in other systems of mental philosophy, devised in the closet, and the actions of men forced into an unnatural alliance with them. The same power that arranged the constellations of the heavenly bodies, and traced for each its appointed orbit, also arranged the organs of mind, and allotted to each its proper sphere of action.

ORDER I.—FEELINGS.

GENUS I.—PROPENSITIES.

COMMON TO MAN WITH THE LOWER ANIMALS.

Situated at the base of the brain, at the sides, and at the back and lower part of the head.

PERSONAL IDENTITY.

Situation—Supposed to be in the base of the brain.

Use.—Gives the consciousness of existence, and the conviction that we are the same person to-day that we were at a former period, or will be at any future time of our lives—identifies us with the flow of time, gives an interest to the hopes of futurity, and stamps with the impress of responsibility the actions of the past.

LOVE OF LIFE.

Situation—Supposed to be in the base of the brain, towards the back part of the head.

Use.—The desire to enjoy existence to an extent suitable to the happiness of the individual, in harmony with the well-being of the species to which it belongs. It tends to the preservation of our own life, and carefulness of the lives of others; gives a desire to enjoy life as a blessing, and to promote by proper means bodily and mental health.

Over Activity.—Disposes to gloomy melancholy, and a slavish fear of death. Life is shorn of its beams, and despondency yields to despair. The individual cannot enjoy life, he is so sore afraid to die. And, strange anomaly! self-destruction often puts an end to his sufferings.

Inactivity.—Produces a recklessness of danger, and diminishes the regard due to the sanctity of life.

+ ALIMENTIVENESS.

Situation.—In the inferior surface of the middle lobe of the brain. When the development is large, it gives a swelled and rounded appearance to the head at the temporal arches, before and a little below the opening of the ear.

Use.—The desire of food necessary for the preservation of life, the removing the painful and uneasy sensation of hunger, and the selecting of food best adapted to the particular organization of the animal.

Over Activity.—Leads to unnatural indulgence in gluttony and drunkenness, with an inordinate desire for unnecessary stimulants in the shape of tobacco, opium, alcohol, &c.

Inactivity.—Disposes to temperance in eating and drinking.

1.—AMATIVENESS.

Situation.—In the cerebellum, or little brain, which lies in the lower and posterior portion of the skull, immediately under the cerebrum, or brain proper, and behind the top of the spinal marrow. The external indications of this organ are a fulness of the back and lower part of the head, and, when full, an unusual distance between the bony prominences behind the ear, where the rotundity and thickness of the neck will be observed.

Use.—The attachment of sex. It produces the feeling of love and affection, and has for its end the continuation of animal existence to an extent consistent with the well-being and happiness of the species to which the individuals belong. It gives warmth to character, and conduces to softness of temper and kindness of manner.

Over Activity.—Is fraught with innumerable evils, and the consequences of immoral gratification are transmitted with painful reality to the innocent victims of succeeding generations.

Inactivity.—Predisposes to passive continence, gives a retiring disregard to the welfare of the other sex, and an unsocial coldness of character, that detracts much from that amiableness of disposition so necessary in the sum of human happiness.

2.—PHILOPROGENITIVENESS.

Situation.—Immediately above Amativeness, and is distinguished by a protuberance, which gives a drooping appearance to that part of the head. It is generally larger in females; when deficient, the back of the head assumes a flat or level form.

Use.—Produces tenderness, parental affection, and love of offspring. Beautiful is the adaptation of this feeling to its related object—no being is so helpless as infant man—no care is equal to that of maternal love—its weakness is a mother's strength—its cries are echoed by an "angel's whisper"—and its tears are mingled with the flood of life. It is a mother's care to draw the dreaming soul from its embryo form, to shield its opening blossoms, and bend with gentleness its budding faculties; nor does the strength of this feeling expend itself beside the cradle where an infant dreams, it infuses a holy calm around the bed of sickness and of suffering, and luxuriates in shadow and in sunshine in the chamber of death.

Over Activity.—Leads to excessive indulgence to pampering and spoiling children, with a want of firmness in denying their improper requests, and excessive sorrow at their loss or removal.

Inactivity.—Produces insensibility to the pleasures arising from attachment to offspring, and an indifference to the weakness of tender objects.

3.—INHABITIVENESS, or CONCENTRATIVENESS.

Situation.—Immediately above Philoprogenitiveness, and below Self-Esteem.

Use.—Attachment to country, love of home, and permanence in place. It also tends to bend the mind continuously to a single or definite object. It gives unity and strength to written composition, and a vigour and dignity to the expression of sentiment.

Over Activity.—Bends the mind intensely on subjects perhaps of minor importance; gives an aversion to the active duties of life, and induces to home sickness. In written composition, the style assumes a laconic and abstracted form, and becomes ambiguous from paucity of expression.

4.—ADHESIVENESS.

Situation.—At each side of, and rather above, the organ of Philoprogenitiveness.

Use.—Gives the desire to attach ourselves to, and cling to living and lifeless things. It is the soul of friendship. In the beginning man was created, and a helpmate was provided for him. In woman, man found his truest and most faithful friend—friendships, formed in the spirit of love and sentiment, are devoted and enduring—kings may league to fetter freedom—bigots may combine to crush the blossoms of the opening mind—pirates may confide in pirate fealty, and traitors write their vows in blood—all these may fail, and all their bonds be fragile as a rope of sand—but friendship, whose soul is sentiment, is lasting as the term of life, nor prison walls, nor deep dark dungeon gloom, nor flux of years, can break its spell.

Over Activity.—Has a tendency to continue attachments to persons who have proved themselves unworthy, and to express itself in the most extravagant paroxysms of grief at the removal or death of those whom they esteem.

Inactivity.—Produces a careless indifference about others.

5.—COMBATIVENESS.

Situation.—On each side of Philoprogenitiveness, and lies immediately behind and above the level of the ear, giving a rounded fulness to that part of the head.

Use.—Gives the ability to meet danger fearlessly—forms the basis of the moral quality of courage, enabling its possessor to extricate himself from sudden and imminent danger. It is of great value, by giving enterprise and energy to face injustice, and to look undaunted on a contest, and to meet it without shrinking.

Over Activity.—A tendency to oppose and attack—loves contention, courts opposition, and provokes resistance. In children it appears in a spirit of contradiction. In more advanced life, expressing itself in irritability and contention.

Inactivity.—Produces timidity of character, the individual will not be able to bear up against the ills of life, to contend with danger, or resist injuries.

6.—DESTRUCTIVENESS.

Situation.—Immediately above, and extending a little backward and forward from the external opening of the ear, giving a full and rounded appearance, with a proportional width at that part of the head.

Use.—The power to overcome and subdue the numerous agents of nature, to destroy what is noxious for self-preservation, to kill animals for our food, and to defend us from the attacks of the unprincipled of our own race.

Over Activity.—Shows itself in the destruction of everything of ornament or public utility, the defacing of milestones, the breaking of railings, and the throwing down the parapets of bridges, display its extent; irascibility of temper, harshness, severity, tendency to torment, cruelty, murder, &c., speak the broad field of its operation.

Inactivity.—Gives rise to passive meekness and softness of disposition; and unfits the individual for bearing up against the numerous evils of life, or taking a leading part in the affairs of society.

7.—SECRETIVENESS.

Situation.—Immediately above Destructiveness, in the middle of the lateral portion of the brain.

Use.—To prevent the improper expression of the other faculties, which it might be improper to disclose, until approved of by the judgment. It gives a watchful prudence to character.

Over Excitement.—Produces cunning, duplicity, and falsehood, with great imprudence and hypocrisy.

Inactivity.—Predisposes to simplicity and innocence of manners, and unfits the individual for being intrusted with the confidence of another; he in whom this faculty is deficient, cannot conduct his own affairs with propriety.

8.—ACQUISITIVENESS.

Situation.—Immediately in front of Secretiveness, and below Ideality.

Use.—The desire to acquire or to accumulate whatever the other faculties may desire, as money, paintings, books, &c.

Over Activity.—Produces excessive selfishness, sordid avarice, and theft; when the pursuit of wealth becomes the chief business of life, and avarice engrosses the whole moral and intellectual man, then is the love of money the root of evil.

Inactivity.—Leads to carelessness in providing for old age, or making provision for sickness; leads to wasteful profusion and extravagant expenditure.

9.—CONSTRUCTIVENESS.

Situation.—In the region of the temple, in front of the ear, presenting a rounded fulness at that part.

Use.—Gives the desire and tendency to construct. Is therefore necessary to architects, engineers, painters, sculptors, milliners, &c.; imparts a desire to protect ourselves by buildings or clothing from the inclemency of the weather.

Over Activity.—Leads to wasteful expenditure in building, and to prodigacy in the construction of weapons of war and engines which are intended for the purposes of destruction.

GENUS II.—SENTIMENTS.

The organs of the sentiments are situated in the superior or coronal region of the brain, and, when large, impart both a breadth and elevation to that part of the head. The sentiments advance man a step higher in the scale of mind, and exhibit him endowed with a class of feelings, which, besides giving rise to inclinations, impart an emotion or affection which is not a mere propensity. These powers of the mind are in consequence called sentiments, and are divided into two classes—the inferior and the superior. The first is called the inferior, because they contain a certain alloy of animalism, and are consequently common to some of the inferior animals and to man. The second is called the superior, because they, being the higher powers of man's nature, sit in judgment over his other powers, and guide and direct them in their legitimate sphere of action. They constitute man an accountable being, his responsibility being proportioned to the strength of their manifestations.

I.—INFERIOR SENTIMENTS COMMON TO MAN AND OTHER ANIMALS.

10.—SELF-ESTEEM.

Situation.—At the top and back part, immediately above Concentrativeness, and below Firmness, giving a considerable elevation and fulness to that part.

Use.—Imparts to man a confidence in his own talents, and, when accompanied with good moral sentiments, gives to him a dignity and native nobleness of character that raises him above doing a mean or dishonourable action. No man can be a great man without self-esteem; before he can command the respect of others, he must respect himself. It is a safeguard to good conduct, because it inspires its possessor with ambition to merit, and confidence to deserve applause.

Over Excitement.—Shows itself in pettishness and wilfulness of temper, and leads to arrogance, pride, insolence, love of power, and tyranny.

Inactivity.—Disposes to humbleness of mind, clownish bashfulness, and false modesty.

11.—LOVE OF APPROBATION.

Situation.—In the lateral and posterior portion of the brain, on each side of Self-esteem, giving great fulness and breadth to that part of the head.

Use.—It gives a desire for the good opinions of others, and induces to that conduct which will render the individual agreeable and pleasing. It leads to emulation, taking the name of ambition when the object is great and important; but when its object is trifling, it degenerates to vanity. It tends to increase happiness by its desire to please. It is of itself a motive sufficiently powerful often to compel the worthless to be wise, the niggard to be generous, and the cruel to be merciful.

Over Activity.—Produces vanity and envy, and gives a love of vain-glory, flattery, notoriety, and foppery. It leads to an ostentatious and vain display of power, of talent, and of kindness. Its alms are given before many that they may be seen.

Inactivity.—Gives a timid and retiring disposition.

12.—CAUTIOUSNESS.

Situation.—In the lateral portion of the brain, farther forward, and in a line with Adhesiveness and Love of Approbation.

Use.—Gives a tendency to carefulness and circumspection, and imparts a disposition to weigh scrupulously the consequences of an action before undertaking it.

Over Activity.—Produces fear, timidity, anxiety, and irresolution, and gives rise to gloomy apprehensions, despondency, and melancholy.

Inactivity.—Gives rashness and imprudence, with impetuosity and recklessness of disposition.

II.—SUPERIOR SENTIMENTS PROPER TO MAN.

In the exercise of the superior sentiments, man graduates from the level of the animal, and approximates to a state of moral excellence, that brings him nearer in perfection to the great First Cause, and places him at the head of the visible creation.

13.—BENEVOLENCE.

Situation.—The upper and fore part of the head, immediately above the brow. It is known by the elevation it gives to that part.

Use.—It produces a kind and merciful disposition, which extends itself to every sentient being. The individual is amiable in his temper, generous in his actions, and charitable in his opinions of the actions of others. The moral virtue of this feeling is placed above all the others in the Christian code—the poor, the afflicted, and the dying are its proper objects. It governs the lower propensities with a greater sway than even the reasoning powers. A man is amiable when reason leads him to do justice; but place justice in juxtaposition with benevolence (which is mercy), the action loses its value by the sternness of the obligation. He that acts from justice only, is cold and indifferent to the wants of others—he that acts from benevolence, abounds in acts of kindness.

Over Activity.—Degenerates to wasteful profusion, which, bestowed on the undeserving, increases rather than diminishes the misery intended to be relieved. It cannot resist tales of distress, whether real or otherwise. It becomes the dupe to every scheme of itinerant impostors.

Inactivity.—Renders the individual careless of the welfare of others, disobliging, and selfish; unless he has some end to serve, it is impossible for him to do a kindly action.

14.—VENERATION.

Situation.—Immediately behind Benevolence, in the coronal region of the brain.

Use.—It gives a tendency to venerate superiority in general; when directed towards the Supreme Being, leads to religious adoration—when under the influence of the Intellect, venerates intellectual character; if Acquisitiveness, riches is then its object. It is directed much by the other faculties.

Over Excitement.—Leads to superstition, fanaticism, a blind reliance on ancient institutions and customs, and an abject submission to superiors and individuals in authority.

Inactivity.—Gives a harshness to character, and a disregard to the finer sensibilities which render social life agreeable.

15.—FIRMNESS.

Situation.—Behind that of Veneration, on the summit of the head, to which it gives a towering appearance.

Use.—Gives perseverance to character, with a uniformity and steadiness of conduct, and bends the other powers to a continuous state of action.

Over Activity.—Leads to stubbornness of purpose, obstinacy of character, and self-willed tenacity of opinion.

Inactivity.—Renders an individual vacillating and unsteady.

16.—CONSCIENTIOUSNESS.

Situation.—The coronal region of the brain, on each side of Firmness.

Use.—Gives the sentiment of justice, imparts a love of truth, with an unbending integrity and proper respect for the rights and property of others. It does not give ideas of right and wrong, but these once formed, it binds the individual to a compliance with their dictates.

Over Activity.—Gives excessive fear of judging wrong, and a desponding remorse at every act of the most trifling injustice.

Inactivity.—Leads to carelessness of the rights of others.

17.—HOPE.

Situation.—In front of Conscientiousness, and at each side of Veneration.

Use.—Gives the tendency to anticipate the fulfilment of what the other faculties may desire. With Veneration it looks forward to futurity, and with Wonder impresses a strong belief in a world to come. It gives to its possessor a tendency to be gay and cheerful.

> "Hope sets the captive free, while fetters bind his limbs—
> And to the sick shows rosy health,
> And riches to the poor."

It enables its possessor to live in the enjoyment of brilliant anticipations. Cautiousness may overshadow his prospects with clouds of uncertainty, but Hope dispels the clouds and dissipates the gloom. The miser care of Acquisitiveness may sink beneath the loss of wealth, but Hope never sinks. The love of approbation may wither in the nipping breath of neglect, and wounded worth may sicken and may die beneath

> "The world's dread laugh,
> Which scarce the stern philosopher can scorn;"

but balmy Hope will soothe the pang, and bid the lingerer live; for yet a brighter sun will rise and cheer him into fame. A despotional veneration may produce unworthy sentiments of self-debasement, but Hope will lift the prostrate victim, dash away the tear that dims the eye, and, with unsparing hand, fling light and loveliness around the portals that are to open on "another and better world."

Over Activity.—Gives rise to unfounded expectations, rash mercantile speculations, and trusting to improbable events.

Inactivity.—Leads to lowness of spirits, crushes exertion, gives uncertainty to our schemes, and inability to struggle with the difficulties of life.

18.—MARVELLOUSNESS.

Situation.—Above Ideality, and below Hope.

Use.—Gives a spur to inquiry, and promotes discovery by the delight it takes in the marvellous and the mysterious, and tends, above all the other faculties, to the formation of religious feeling.

Over Activity.—Gives a tendency to believe in presentiments, phantoms, and familiar spirits, and leads to excess in every kind of irrational fanaticism and superstition.

Inactivity.—Leads to scepticism and unbelief.

19.—IDEALITY.

Situation.—Above Acquisitiveness, and below Hope and Wonder, extending backward toward Cautiousness.

Use.—Gives an emotion of the sublime and beautiful, indulges in the contemplation of infinity, and delights to clothe the object of its veneration with the attributes of perfection—it invests everything with fancy, and gives a meaning to all it sees—it gives a finer and a deeper tone to our sensibilities—it kindles a glow of warmth in the feelings by the loveliness of its imagery—it awakens the judgment by the facility of its conclusions—it gives a taste for ornament and elegance—and a value to works of art, and seems added to our other faculties merely for the purpose of contributing to our happiness.

Over Activity.—Has a tendency to indulge in fanciful and utopian schemes, to the neglect of the more useful duties of life, leads to enthusiasm in trifles, and gaudiness and show.

Inactivity.—Tends to indifference to the beauties of nature, to coarseness of taste, and inelegance of manner.

20.—WIT.

Situation.—At the side of the forehead, between Causality and Ideality.

Use.—Imparts a sense of the ludicrous, and a quick perception of the meaning of others. It seems given for the purpose of disposing us to be pleased, and affording an additional source of gratification and happiness.

Over Activity.—Has a tendency to irony, sarcasm, and satire.

21.—IMITATION.

Situation.—In the upper part of the sides of the forehead, and on each side of Benevolence.

Use.—Gives the tendency to do as others do, and assimilates the manners of individuals to a suitable uniformity with each other. It is of permanent importance to the mechanic, the painter, and the sculptor.

Over Activity.—Gives a disposition to ridicule the failings of others, and disposes to buffoonery and mimicry.

ORDER II.—INTELLECTUAL FACULTIES.

Situated in the forehead. Through their means we derive almost all the knowledge we possess: they form three separate and distinct classes—the external senses, and the perceptive and reflective faculties.

GENUS I.—THE EXTERNAL SENSES.

SEEING, HEARING, TASTING, SMELLING, AND TOUCHING.

By the instrumentality of these senses, man is ushered into the arena of knowledge, the world with its numerous objects is opened to his view, their physical qualities made known, and the relationship disclosed that exists between them.

GENUS II.—PERCEPTIVE FACULTIES.

22.—INDIVIDUALITY.

Situation.—In the centre of the lower part of the forehead, immediately above the root of the nose.

Use.—Gives an aptitude for practical observation, which enables its possessor to acquire knowledge by abstract or detached means; it greatly adds to our powers of conversation. It constitutes a quick observer, but not a deep thinker.

23.—FORM.

Situation.—Immediately at the root of the nose, and below Individuality.

Use.—To perceive clearly the form of bodies, communicated to it through the medium of the external senses of touch and seeing. It is essential in the arts of sculpture, portrait-painting, &c., and enters as an important constituent in the formation of a mechanical genius.

Over Activity.—Leads to fastidiousness in dress, &c.

24.—SIZE.

Situation.—Over the inner angle of the eye, immediately above the root of the nose.

Use.—To perceive the size of bodies distinct from form—the form of a body may be the same, and the size may be decidedly different. It is an important faculty to geometricians, architects, carpenters, portrait-painters, and others who require to take dimensions.

25.—WEIGHT.

Situation.—Toward the inner corner of the eye, between Size and Colour.

Use.—Gives the estimate of gravity. All who excel in archery, ball and quoit play, in skating, fencing, and horsemanship, are endowed with a large development of this organ. It is essential to the investigation of mechanical forces. To slaters and building masons it is indispensable, and enables them to do their work by sight, while others, who are deficient, can scarcely perform by aid of instruments.

26.—COLOUR.

Situation.—At the middle of the arch of the eyebrow, giving to it sometimes a rounded appearance, at other times an angular configuration directed upward and laterally.

Use.—To distinguish, mix, and enjoy colour.

Over Activity.—A fondness for gaudy and glaring colours.

27.—LOCALITY.

Situation.—On each side of the organs of Individuality and Eventuality, extending upwards as far as the organs of Wit.

Use.—To take cognizance of the relative position of objects. It gives the power of recognizing places formerly seen, imparts a fondness for travelling, and constitutes a chief element in the talent for topography, geography, astronomy, and landscape painting. It assists the traveller in finding his way to places he has formerly visited, and giving him an accurate and vivid recollection of them.

Over Activity.—Gives a restless rambling disposition, and a great desire to see foreign places.

28.—NUMBER.

Situation.—Immediately over the external opening of the eye.

Use.—Gives a knowledge of the power of numbers, a facility to calculation, in arithmetic, algebra, and in mathematics.

29.—ORDER.

Situation.—Between the organs of Number and Colour.

Use.—A love of neatness and order—it gives a tidiness of dress, and a conscientious regard to appointments—it is annoyed by confusion, and manifests a pleasure in the arrangement of things—it is a valuable endowment in the mistress of a house.

Over Activity.—Leads to irritable impatience at the slightest deviation from order and uniformity in others.

30.—EVENTUALITY.

Situation.—In the middle of the forehead—when full, giving a round, rather than a flat appearance to that part of the head.

Use.—To take cognizance of occurrences both active and passive, whether connected with, or having relation to objects—recollects events, and makes remarks of particular phenomena of Form, Colour, Size, Number, Order, &c., and takes observations of things following, and traces the events dependent upon the activity of these phenomena.

31.—TIME.

Situation.—Out from the organ of Locality, extending upward to Causality and Wit, and outward to Tune.

Use.—Gives the perception of duration, and marks its silent movement. It is a key to music, and poetry is deficient without it. It gives life to business, and promptitude to appointments.

32.—TUNE.

Situation.—In the lateral portion of the forehead, and nearly on a line with Time.

Use.—Like Ideality, it seems an ornamental attribute, given to man as a source of one of his purest pleasures; none has such command over his other faculties as that of Tune. The sound of the trumpet rouses his combativeness to deeds of martial bravery, and the mellow softness of the flute melts the soul to love—music steals into the mind of the melancholy man with a pervading sweetness, and expands the jocund countenance of mirth—it brightens the eye of grief, and chastens the tear of affliction—it awakens the intensity of wonder, and animates the pleasures of hope—it gives depth and tone to veneration, and leads the soul in harmony to the sublimity of devotion.

33.—LANGUAGE.

Situation.—Under the plate-bone that forms the roof of the eye, giving it the appearance of being pushed forward and downward.

Use.—Gives a facility of acquiring and using language. Speech is defined to be the use of abstract signs or symbols, the representatives of preconceived ideas. Language is the art of persuasion, and whether written or spoken, is the medium through which we communicate our acquired knowledge to others. Eloquence is language prompted by one or more of the faculties in vivid activity.

Over Activity.—Has a tendency to overload every subject with words, giving to written language and conversation a cumbrous and unpleasing redundance of expression.

GENUS III.—REFLECTIVE FACULTIES.

34.—COMPARISON.

Situation.—In the centre of the upper region of the forehead, immediately above Eventuality, and between Causality.

Use.—Gives the facility of perceiving resemblances and analogies, and a tendency to compare one thing with another, and disposes the individual who has it large, to use similitudes in writing and discourse.

Over Activity.—Leads to hasty and inaccurate judgment, resulting from appearances rather than reality.

35.—CAUSALITY.

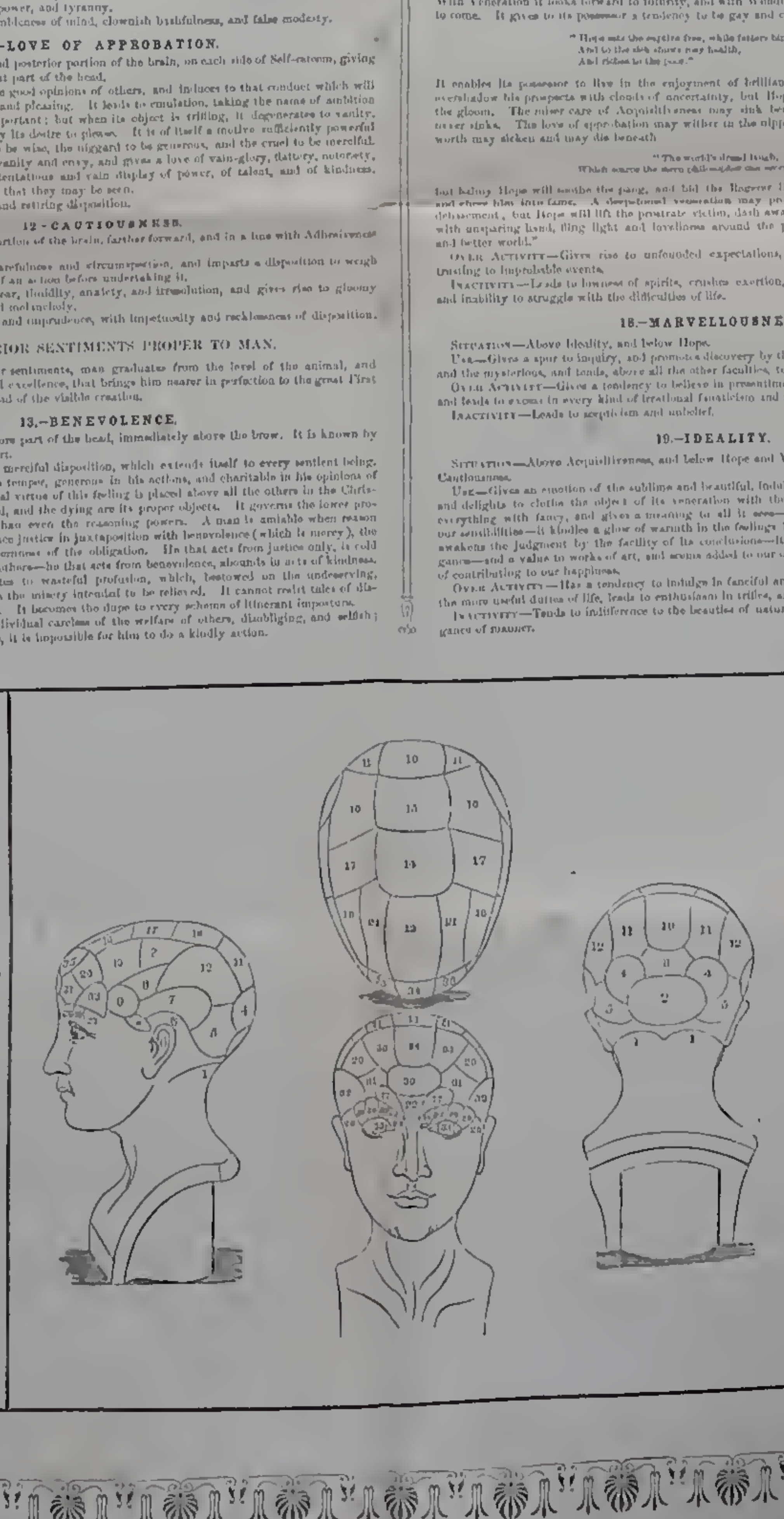
Situation.—On each side of Comparison.

Use.—Imparts a talent for logical reasoning and inductive philosophy. It gives the idea of the relation between cause and effect—it has a sphere especially its own—it is the province of Individuality and Eventuality to judge from facts, Causality draws its conclusions from the evidence of circumstances. Jurymen, with a full development of the former, will not be disposed to convict upon circumstantial evidence. To the latter, such proof would be irresistible. The true philosophical understanding of things is the result of a well-defined development of the organs of Individuality, Eventuality, Comparison, and Causality. The two first make us acquainted with facts and phenomena—Comparison informs us of their identity or difference, and Causality necessarily infers a first cause, or moving power.

Over Activity.—Renders an individual doubting, incredulous and distrustful, dogmatical and narrow minded. Those who have a large development of this organ, reduce men's minds to their own standard, supposing the cause that operates upon their own actions must be the same that regulates the actions of others.

KEY TO AUTHORIZED CHART.

Personal Identity.
Love of Life.
+ Alimentiveness.
1. Amativeness.
2. Philoprogenitiveness.
3. Concentrativeness.
4. Adhesiveness.
5. Combativeness.
6. Destructiveness.
7. Secretiveness.
8. Acquisitiveness.
9. Constructiveness.
10. Self Esteem.
11. Love of Approbation.
12. Cautiousness.
13. Benevolence.
14. Veneration.
15. Firmness.
16. Conscientiousness.



KEY TO AUTHORIZED CHART.

17. Hope.
18. Wonder.
19. Ideality.
? Unascertained.
20. Wit.
21. Imitation.
22. Individuality.
23. Form.
24. Size.
25. Weight.
26. Colour.
27. Locality.
28. Number.
29. Order.
30. Eventuality.
31. Time.
32. Tune.
33. Language.
34. Comparison.
35. Causality.

houses. If the British people have realized so much that is good in darkness, what will they not accomplish in the light?

But it may be asked, what of those who reside where public libraries cannot be established, and where the sparseness of population, or the hostility of influential persons, renders institutions impossible? And, again, is it not essential that the working man should possess a few well-selected books for more constant reference? This brings us to the last, though by no means the least, agent in the great task of popular education—cheap literature. Did space allow, we would gladly sketch the history of this modern improvement, and add our tribute of praise to the worthy men who have been its pioneers. Much, doubtless, that has been published at low prices is frivolous or demoralizing, but still a prodigious amount of sound instructive matter has been placed in the hands of the people. The amount of the latter kind would be relatively far greater were it not for the "taxes on knowledge," which, as Mr. C. Knight has shown, press more heavily upon a cheap periodical the more carefully it is got up. We cannot here discuss this important question, but we must remark, that to maintain "African squadrons," at the expense of keeping Englishmen in ignorance, is in very deed "taking the children's bread, and casting it to the dogs." We detest slavery as much as any man, but if it can be prevented only by depriving our countrymen of the means of education, we would have all remember that justice, no less than charity, begins at home. As far as instruction is concerned, those works will be found most useful to the labouring classes which give a condensed and well-arranged view of the whole field of science. To the man whose mind is as yet untrained, it is a difficult task to turn from one volume to another, and to compare conflicting statements. A work of this comprehensive nature forms a kind of nucleus or kernel, about which all knowledge derived from various sources may be grouped. In such books, whilst omitting nothing of importance, we should carefully shun whatever is superfluous, or still undecided, remembering that we address men whose time is limited, and who are not as yet prepared to sit in judgment on open questions in philosophy. The serial form, now very extensively adopted, offers two considerable advantages. It is not only easier for a working man to buy, but to read, a book when placed before him by instalments. We sometimes forget, that to persons accustomed chiefly to manual labour, a bulky volume has a very formidable, nay, a forbidding aspect. The consequence is, that he either shuns the task altogether, or turns over the pages in a desultory manner, reading here and there a portion, and thus acquires habits very unfavourable to self-improvement; whereas, if the work is placed in his hands in monthly portions, he may make himself master of one section before encountering the next. We have heard it intimated, that cheap periodicals had, in some degree, tended to draw away the people from Mechanics' Institutions. This we do not credit. The cheap book or serial, if properly studied, will raise a desire for more profound and extensive information, and will thus conduct, as it were, the working classes to the free library or the Mechanics' Institution. There is room enough, and more than enough, for all the various agencies of instruction, and our only ground for apprehension is lest even their combined action should prove insufficient.

THE SCIENCE OF PHRENOLOGY.

CHAPTER II.

Further remarks on Size—Its General Application—Size modified by Temperament—Theory of the Temperaments—External Signs for distinguishing the Temperament—Antagonisms—Grouping of the Organs.

We have replied to the principal objections urged against the science of phrenology by ministers of the gospel, (Vol. I. p. 472,) but there is an objection urged by anatomists, which we have in part anticipated, (p. 474,) which is to the following effect—namely, "That there is no cognizable division of the brain into separate portions, corresponding to the so-called organs of phrenologists." To this we reply, such a division is by no means necessary for the establishment of the truth of the science. It is quite possible that the blood, in passing through the different parts of the brain, may in one part excite, stimulate, or produce the faculty of secretiveness, while in another it may excite, stimulate, or produce that of conscientiousness, while the brain may still appear homogeneous in structure, and apparently composed of one mass. This is no more than occurs in other parts of the body. The nerves of motion and sensation are enclosed in one common sheath, and there is no line of demarcation to mark where the one terminates and the other begins; and there is, besides, no perceptible difference in their structures, yet their functions are as widely different as the two faculties of secretiveness and conscientiousness just above named. Anatomists cannot discover the functions of the brain, nor are they capable of discovering the function of any organ. It is a general law of nature, that each function must have a separate organ. This proves that the brain cannot be a single organ, (see p. 473,) but a congeries of organs. In accordance with this law, Dr. Spurzheim, long before the discovery was made, affirmed that there must be separate nerves for motion and sensation. Sir Charles Bell has demonstrated this to be the case, and by this has added another illustration to the law, that every function must have its own organ. The analogy of the other parts of the body, therefore, are in favour of the phrenological doctrine, that the brain, although apparently one homogeneous mass, is in reality a congeries of distinct organs, manifesting distinct and separate functions.

We have already stated (p. 474) that size, other conditions being equal, is an index of power. This is one of the fundamental doctrines of phrenology; and as several objections have been brought against it, we are anxious to establish its truth. In their objections, the qualification, *cæteris paribus*—that is, other things being equal—has been entirely overlooked by our opponents. It is affirmed that the largest or heaviest man is not always the strongest; but this arises from the difference of temperament or constitution, which we shall illustrate presently. A man may be large and bulky, but there may be more water and fat about him than muscular fibre. But of two men, of the same temperament, and equal in every other condition, the one who has got the larger muscles will be proportionally stronger than the other. This is saying nothing more than the established mathematical axiom, that the whole is greater than a part. The maniac often exerts more strength than another man of equal temperament and size of muscle, but the conditions are not equal. The nervous influence sent to the muscles in the time of furious madness, far exceeds what is sent to the muscles at other times, and this accounts for the greater degree of power manifested.

The principle that size is a measure of power, pervades the whole of nature, inorganic as well as organic. The bar of iron two inches square, is stronger than that which is but one inch square. The function of the liver is to secrete bile; the larger the liver is, the more bile will it secrete. A liver eight inches square will secrete more bile than one four inches square. The more capacious the lungs are, the better will they perform their function of aerating the blood. The left ventricle of the heart is much thicker and stronger than the right ventricle; for this reason, that the former has to send the blood through

the whole of the body, from the very top of the head to the sole of the foot, while the latter has merely to propel the blood to the lungs.

In some structures of the body, the nerves of motion preponderate over those of sensation; while, in others, the nerves of sensation are much larger than those of motion, and the manifestations are invariably in accordance. Again, those parts of the body which are possessed of little sensation, are feebly supplied with the corresponding nerves, while in every sensitive part, such as the hand, the nerves of sensation are very large. The whole sum of sensitive nerves which go to the liver (an organ possessed of little feeling), is no greater than those sent to the *thumb*, which is not the fiftieth part of the size of the liver. The analogy holds equally good, if we descend to the inferior animals. The mole has the olfactory nerves very largely developed, while the optic nerve is very feebly so; and this is strictly in accordance with its known character. In the eagle, however, the case is reversed, the optic nerve being very large, and the olfactory very small. The extreme power of vision possessed by the eagle is known to every one. The same holds good with regard to the auditory nerve; and from all these cases it is reasonable to infer, that the brain forms no exception to what appears to be the universal law of creation.

But there are circumstances which modify the effects of size. These depend upon the constitution, or upon what physiologists denominate the temperament.

The view taken of the temperaments by Dr. Caldwell, an able physician of the United States, seems to us the most in accordance with nature, and accordingly we transcribe it.*

"The human system is composed of a number of organic tissues, serving in the capacity of proximate elements of larger and more compound organs: and these elementary parts differ from each other, not only in substance, structure, and function, but also in vitality, activity, and power. In the composition of the bodies of different individuals, these tissues exist in different proportions. And according as one or more of them predominate in quantity, are the constitution and character of the person of whose body they make component parts. We proceed to illustrate this statement by a few specifications, containing a succinct account of some of the elementary tissues.

"Of these, the osseous, cartilaginous, and fibrous, are comparatively of an inferior order; possessing as they do but a very limited degree of life, they contribute but little to either the production or the modification of character. They serve as mere machinery to be operated on, and thrown into action by other parts, superior in material, organization, and endowment, and therefore corresponding in power and standing.

"Of the cellular, serous, and mucous tissues, the same is true, though in a more limited degree. So is it of every other structure whose life and functions are little else than vegetative. Though indispensable as elements in the composition of the body, and therefore essential to health and well-being, those tissues are feeble in their bearing on the formation of character.

"The tissues which act the most important part in forming and modifying the constitution of the character, are the muscular, the sanguiferous, and the nervous—the last including the brain and spinal marrow. The muscles most influential in their contexture with temperament, are the heart, and those which subserve immediately respiration and digestion. Of these, the chief respiratory muscles are the intercostals and the diaphragm; and the digestive are those that enter into the structure of the alimentary canal. In the production and modification of temperament, the lungs are also, as will appear hereafter, though somewhat indirectly, yet very peculiarly important in their agency. They are deeply concerned in making the blood, and exclusively so in endowing it with life. And in the course of its circulation, that fluid again, especially the arterial portion of it, imparts life, and vigour, and efficiency to every solid belonging to the body. Hence an organ, if deprived of it by ligatures on its arteries, or by their obstruction in any other way, immediately perishes; and hence the sudden and inevitable fatality of a profuse loss of blood.

"From these considerations it is obvious, that the agency of the sanguiferous tissue in the original formation of temperament, and in the changes which it subsequently undergoes, is important and striking; for in no individual, in any period of life, is temperament *positively stationary*. From infancy to old age, its changes, though usually gradual and slow, are notwithstanding incessant.

"Of all the organic structures that enter into the composition of the body, the nervous is pre-eminently the master tissue—of the highest order, I mean, in vitality, power, and function. In the entire range and bearing, therefore, of its influence on temperament, it is paramount to either of the others singly, if not to the whole of them united. Without it, man, though in all other respects the same as at present, would be inferior in standing to the insect or the worm—so true is it, that we are only what our organization makes us.

"Next to the nervous in its influence on temperament is the sanguiferous tissue. Even the nervous itself is essentially dependent on it for all it possesses of power and efficiency, and even of life; for without a sufficient supply of arterial blood, every organ of the body, the brain not excepted, would fail, not only in action and vigour, but in vital existence.

"Conformably to these views of the subject, which are believed to be themselves in strict conformity with truth and nature, it is easy to account for the formation and being of the nervous and sanguineous temperaments. They are simple in their composition, and therefore, in their constitution and character, easily understood. As their names import, they arise severally from the respective predominance of the nervous and sanguiferous tissues, and possess, of course, endowments corresponding to the nature and attributes of these two elements of animal organism.

"But there exist two other temperaments, accounted also original and simple, the constitution of which is but little understood—perhaps I should say, not understood at all. They are the *bilious* or *choleric*, and the *phlegmatic* or *pituitary;* the former distinguished by the attributes of active energy, vigour, and endurance, under excitement, exertion, and toil, which it imparts to its possessors; the latter, by a condition in no small degree the reverse of this—a condition unaccompanied by any elevated and efficient qualities, corporeal or mental.

"Were the question proposed, 'What are the natural elements or organic constituents of these two temperaments?' to render an answer intelligible and satisfactory would be a difficult task. As far as my knowledge of the matter extends, such an answer is yet to be framed; but the following analogical remarks are submitted to the attention of the reader:—

"The effects of dryness and tension on a drum head, the strings of a violin, the wires of a harp, and on other elastic and sonorous bodies, are known to every one. So are the effects of a condition in such bodies the contrary of this—I mean of a humid and lax condition. In the former case, the bodies are full of elasticity, activity, and of what may be figuratively called vigour, and are therefore prepared for the emission of sound, and the production, under suitable regulations, of *spirit-stirring* music. But not so in the latter: they are there inactive and unsonorous, lifeless and uninteresting; they possess no sort of efficiency beyond that of common dead matter. Such is the doctrine; and its analogical applicability to the subject I am considering must now be attempted, with what degree of success or plausibility the reader must determine.

"That, in persons possessing what is called the *bilious temperament,* the muscles, and such other solids as can be sufficiently examined, are remarkable for their solidity, firmness, and comparative lack of moisture, will not be denied; and such persons manifest, in action, unusual vigour and energy, and a corresponding degree of endurance under high excitement, hardship, and toil. To employ an expression rather common and homely than classical and elegant, but strong in its meaning, and well understood, they are '*tightly-knit*' in their entire organism—the bones themselves, perhaps, not excepted. All other things being alike, therefore, they are

* See Phrenological Journal for January, 1842, p. 16.

superiorly fitted to be pioneers and labourers, combatants and fatigue-men. But the same solid, tense, and compact condition of fibre which gives them unusual muscular vigour, endurance, and efficiency, confers a like superiority on their nerves and brain. Hence, when the latter organ is large, and its developments favourable, and when, in addition to this, it is thoroughly improved by a suitable education—under these circumstances, such persons cannot fail to be remarkable for their talents and achievements. They are men of severe and persevering study, and ample scientific attainment; or they are distinguished in the direction of practical affairs.

"As relates to the *phlegmatic temperament*, it presents a condition of things in most respects the reverse of this. In those who possess it, the fibres of the body are evidently lax; the globules which form them are no doubt deficient in solidity and firmness; the skin, muscles, and other solids, are flaccid and soft to the touch; and the entire organism superabounds in fluids; especially in some sorts of secreted and aqueous fluids, but not in blood—certainly not in *arterial* blood. And this moist and enfeebling condition prevails in the brain and nerves, no less than in the other organs of the body. Be the cerebral development, therefore, and the education what they may, the mental faculties are of an inferior class, and all sorts of mental action exceedingly moderate, if not imbecile in character. From the foregoing considerations, it would seem that what are called the fibrous and the phlegmatic temperaments, are the result of a condition of things of a nature altogether different from that which gives rise to the other temperaments. The bilious appears to be the product, not of a want of balance between any given parts of the system, whether solid or fluid, but of a state of unusually elevated tension and tone of all the solids. And the phlegmatic temperament arises from a contrary state of the same parts; a deficiency of tensity and tone in the whole of them. Although it has been said, that in the phlegmatic temperament there exists a want of balance between the solids and the watery fluids, the latter being excessive in quantity, that is one of the *effects* of the temperament, not its cause."

Phrenologists are agreed that there are four pure temperaments, which point out the quality of the brain, or degrees of mental activity, viz.:—1. Lymphatic; 2. Sanguine; 3. Bilious; 4. Nervous.

1. The lymphatic constitution, or phlegmatic temperament, is indicated by a pale white skin, fair hair, roundness of form, and repletion of the cellular tissue. The flesh is soft, the vital actions are languid, the pulse is feeble; all indicates slowness and weakness in the vegetative, affective, and intellectual functions.

Lymphatic.

2. The sanguine temperament is proclaimed by a tolerable consistency of flesh, moderate plumpness of parts, light or chestnut hair, blue eyes, great activity of the arterial system, a strong, full, and frequent pulse, and an animated countenance. Persons thus constituted are easily affected by external impressions, and possess greater energy than those of the former temperament.

Sanguine.

3. The bilious temperament is characterised by black hair, a dark, yellowish, or brown skin, black eyes, moderately full but firm muscles, and harshly expressed forms. Those endowed with this constitution have a strongly marked and decided expression of countenance; they manifest great general activity and functional energy.

Bilious.

4. The external signs of the nervous temperament are, fine thin hair, delicate health, general emaciation, smallness of the muscles, rapidity in the muscular actions, vivacity in the sensations. The nervous system of individuals so constituted, preponderates extremely, and they exhibit extreme nervous sensibility.

Nervous.

Those four temperaments are seldom to be observed pure and unmixed; it is even difficult to meet them without modi

fications. They are mostly found conjoined, and occur as lymphatic-sanguine, lymphatic-bilious, sanguine-lymphatic, sanguine-bilious, sanguine-nervous, bilious-lymphatic, bilious-sanguine, bilious-nervous, &c. The individual temperaments which predominate may be determined; but it is difficult to point out every modification.

Besides the temperaments, there is a disturbing element in the estimation of character, which may be termed antagonistic, or the action of those faculties whose functions are in some measure opposed to each other.

Every faculty in the human mind acts in accordance with its specific functions, and its actions are regulated and limited only by the counteraction of other opposing faculties. Thus, Acquisitiveness simply gives the tendency to acquire; and, were it the only active organ in any person's brain, he would incessantly draw and grasp all objects indiscriminately to himself, without any restriction or limitation whatever, having no regard in his accumulations to his own use or convenience, or to the rights of others.

In like manner, were Destructiveness the only active organ, the individual would be nothing else than a mischievous machine; and so on with all the other faculties, whatever be their nature or functions. But when two, or three, or more organs are active, the action of each, although still moving in its own specific direction, is in some degree modified and restrained. Acquisitiveness, when combined with Conscientiousness, is not the less active in its tendency to acquire, but its sphere of action is limited, and a boundary is drawn. Conscientiousness says, "thou shalt not steal," or "thou shalt not covet," and Acquisitiveness is made to obey either command; and the result is, that the individual will be just and honest, although

"He'll gather gear by every wile
That's justified by honour."

Still he will be just and honest, and, if he possess well-developed Love of Approbation and Benevolence, he will expend his acquisitions as well for the public good as for his own. Individuals exemplifying the action of what may be termed antagonistic organs, are frequently to be met with. I know an elderly lady in whom Acquisitiveness and Benevolence are both very energetic, and, were it not for the former of these organs, the latter would certainly become irregular in its action. But constituted as she is, she is rather penurious in laying out her money. Yet she is kind, and has a strong inclination to relieve the wants of the needy; but, instead of taking the money out of her own pocket, she almost always solicits the contributions of others, more wealthy than herself, to effect her benevolent purposes.

I am also acquainted with a mercantile gentleman in this city, whose actions betray powerful Acquisitiveness, Conscientiousness, and Love of Approbation; and, to a person who has acquired a knowledge of the principles of phrenology, it is extremely interesting to observe the uniformity with which his conduct harmonizes with his development. On paying an account, for instance—these three organs being called into play—he very generally uses words to this effect:—"Now, Mr. ——, you must, with your usual liberality, allow me off this odd sum of nine shillings; for really, at the present time, I require to buy as cheap as possible: however, if you say that the goods are as cheap as you really can afford to sell them, I will pay you in full, for I would not wish you to lose by the transaction. Let every man have his due; that's my motto."

The preceding shows the action of organs *partly* antagonistic; but there are two organs whose functions are, we may say, almost completely opposed to each other, which we will now turn to the consideration of. We refer to the organs of Inhabitiveness and Locality. The former gives a love of home, and a desire for permanent residence. The latter, on the contrary, gives a disposition to travel, and to be continually moving from place to place. When they are equally developed, each, of course, pulls with equal force in its own particular direction. But then the question arises, whether will the individual travel or remain at home? This must be settled by circumstances, and by the vote, as it were, of other faculties. If the faculties which would be gratified by his travelling, preponderate over those which would prefer a permanent abode, then (circumstances allowable) he will travel. In thus gratifying Locality, however, his attachment to home will not be annihilated or remain quiescent. On the contrary, it will often annoy him in his rambles. The happiness he would experience in freely roving from place to place will be checked, or, at least, very much alloyed, by the constant desire of returning to his native land, and his heart language would be,

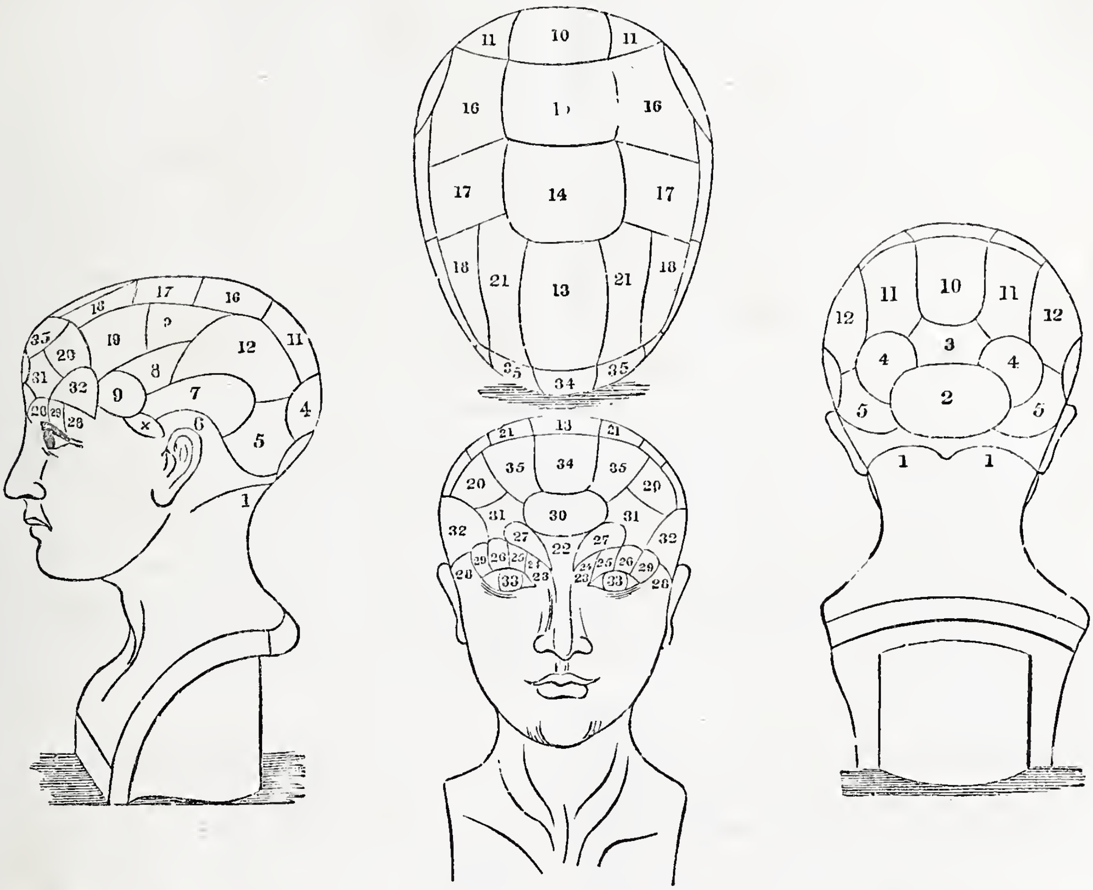
"Where'er I roam, whatever realms to see,
My heart, untravell'd, fondly turns to thee."

He therefore will not be entirely happy, and the probability is, he will be affected by *nostalgia*. He will enter into the spirit of the song, 'Home, sweet home!' and it will be with the warmest emotions be will return to his own country. His pleasure here, however, will often be dashed with sadness; he will like to be roaming again, or, perhaps, compensate the gratification of his propensity by reading lives of eminent travellers, descriptions of foreign countries, voyages, &c. If we suppose the individual with large Inhabitiveness and Locality to be a denizen of our city, and so circumstanced as entirely to preclude him from travelling, or going far from home, we shall find that he will relish very much to walk into the country on a summer morning, and he will, in all probability, gratify himself in this way very frequently. He will visit, and become acquainted with, all the interesting spots round the city. He will be constantly in search of new tours. In the library, he will be found to ask most frequently for such books as give descriptions of countries, buildings, &c. It will from hence be seen that a man's conduct is frequently influenced by the action of what may be termed antagonistic forces or faculties. Each faculty, in proportion to its power, demands gratification, although the mode in which it will be gratified depends upon, or is determined by, the other powers of the mind.

The character of the human mind is either elevated and intellectual, as the brain is fully developed in the fore and upper parts of the head; or it is low, animal, and sensual, as the brain is more fully developed behind the ear, and at the back part of the head.

The brain may be divided into three great regions—highest, middle, and posterior. From the highest of these compartments, a man may be said to regard God, because in this resides the moral and religious sentiments. From the second of these divisions, a man may be said to regard the world and his neighbour, because in this, the intellectual faculties have their seat. From the posterior, or lowest of these divisions, a man regards himself, because in this the animal propensities are located. As the various organs which are now considered established were discovered at different times (see p. 476), one organ being in the orbitar process of the frontal bone (Language), another just above the occipital bone (Philoprogenitiveness), a third at the posterior part of the vertex of the head (Self-esteem), now that the head presents to our view a pretty fully mapped delineation of the various powers of the human mind, we propose to conclude this chapter, by showing that this is, in itself, an argument in favour of the truth of the science. As already observed (p. 476), Dr. Gall did not map out the skull into compartments, and arbitrarily assign a position to each faculty. We observe, by referring to the bust, that the posterior or animal region is occupied by propensities (No. 1 to 9); the sincipital region, by sentiments (10 to 21); and the anterior region, by intellectual faculties (22 to 35). We do not find an intellectual faculty in the animal region, nor an animal propensity in the moral and religious region. Again, we see each organ associated with others best adapted, so to speak, to minister to the aid of the group of which it appears to be a necessary member. Thus, Causality (35) is the support of Comparison (34); Time (32), of Tune (31); Number (28), of Order (29); and so of the rest. Every organ in each division of the brain seems to be confined to its own particular class, and each class, or division, appears to be under the direction of a superintendent. Self-esteem watches over the

propensities, Veneration over the religious sentiments, Comparison and Causality over the intellectual faculties, and Conscientiousness over the whole. In consequence of this, the mind is capable of being raised, and of raising itself upwards, and it can look towards the Great Supreme and his kingdom of heaven. It is capable of being diffused, and of diffusing itself, laterally in every direction, and ean thus look around into this world and its nature, and can render itself useful to every class of the community. And it is capable of degrading and sinking itself downwards, seeking merely animal gratifications, and thus becoming associated with sensuality. And here we may with propriety again ask, what can be a more satisfactory and even beautiful exemplification of what we have just stated, than the arrangement of the organs on the phrenological bust, constituting, so far as discovery has proceeded, a complete map of the mind? Veneration (14), which disposes to the reverential worship of the Great Supreme. Conscientiousness (16), which imposes integrity, uprightness, and love of truth, by which alone the moral and religious duties can be faithfully exhibited before the world. On each side of Veneration, the organ of Hope (17) developes itself—proper situation for so exhilarating a faculty; it seems to depend upon Conscien-



tiousness and Veneration for its blissful anticipations. The object of its reverence it one day hopes to behold, having an ambition for living in a world which

> "Honour, fame, and all this world calls great,
> Can never satisfy."

The certainty of a future state of being, which Hope, aided by Veneration, gives to the Christian phrenologist, enables him with fortitude to bear "the thousand ills to which the flesh is heir." Below Veneration is Benevolence (13), that godlike virtue, which can, even by sympathy, soothe and mitigate the bitterest sufferings, but which, by its active charity, shows its close connection with Veneration, by the love of the brethren derived from the love of God. Thus, the proper situation of Benevolence or Charity is below Veneration. Below Hope, on either side of Benevolence, with Imitation (21) between the two, is situated Wonder or Marvellousness, or, as some have termed it, Inductive Faith (18). Now, can Faith be better associated than in conjunction with Charity or Benevolence, with Hope raised upward, Imitation between Benevolence and Faith, and Conscientiousness overlooking the whole? Behold! here the religious group of faculties becomes established; a group which all but the sceptic will acknowledge to be of the highest consequence, and occupying the supreme region of the head.

The second group of organs, those by which a man is led to regard his neighbour, and do his duty in the world, are a numerous family, but they are as necessary as they are numerous. It is quite impossible to observe with accuracy, unless the faculty of Individuality (22) is fully developed; and as this faculty is the source of minute observation, it is conspicuously placed in the centre between the eyes, at the upper part of the nose. "Everything we love and everything we hate, everything we desire and everything we fear, is an individual. It is by Individuality, therefore, and by what is presented to the mind from Individuality, that all our feelings are excited and brought into activity, and therefore Gall had no little reason to term it the organ of Educability."—(*Phren. Journal*, vol. v., p. 249.) A little below Individuality are the organs

of FORM (23) and SIZE (24), both exceedingly necessary to accurate delineation. WEIGHT (25), COLOUR (26), ORDER (29), and NUMBER (28), belong to the group denominated knowing or perceptive faculties, forming a division of the intellectual group. And here again we are struck with the beauty of the position. The knowing, or, as they may be termed, the scientific organs, take cognizance of two classes of objects—existences and events—or of things as they now are, and things as they may hereafter be. For example, make a solution of carbonate of soda. This is an existence. Again, make a solution of tartaric acid. This is also an existence, though of a different body. Pour the two solutions together, and a violent effervescence takes place. This is an event. Thus, there is existence and event, perception and remembrance. To perceive and remember existences, the perceptive faculties are necessary; and to perceive and remember events, EVENTUALITY (30), LOCALITY (27), and TIME (31), are necessary. Still, however, we are enabled to perceive that every individual does not possess these faculties with the same energy. Form and Size may be freely developed, while Colouring may be imperfectly so; and thus a man may be an expert draughtsman, but be unable with accuracy to discriminate tints and shades in colour. To keep these organs under proper control, to regulate their various functions, another division of this group is called into exercise, at the upper part of the forehead, namely, COMPARISON (34), CAUSALITY (35), and WIT (20), or Discrimination. Here we may close our notice of the second class, with the assumption that they are eminently useful, and their position shows how intimately they are connected with that group which enables us to do our duty in the world and to our neighbour. But there is yet another group which we must briefly notice, and which leads the man chiefly to consider himself. And here we may observe, that there are no bad faculties, as some opponents of phrenology have termed the lower propensities. No faculty in itself is hurtful or useless, and still less criminal; but if we regard only ourself, and take for our motto the detestable apothegm—"Every man has a right to do the best he can for himself"—(every man has not a right to do the best he can for himself, if that right interferes with the right of his neighbour)—then these organs, or rather the abuse of them, are the sources of most of the evils which afflict mankind. But our present purpose is to show that they are all useful, or the Divine Being would not have bestowed them upon us.

The feelings of regard which are necessary to link together so large a family as that which constitutes the human species, must be exceedingly fervent; and though the feelings may differ in intensity, according to the difference of sex and constitution, still the effects will be manifested in those portions of the brain where the affective faculties have been proved to exist. Philosophers have long divided the mind into will and understanding. We see no reason to alter this. We have hitherto treated of those faculties which relate to the understanding, as well as to those feelings which belong to what may be termed the higher affections of the mind. We now come to treat upon the lower feelings existing in the will. The cerebellum, or little brain, is the situation of the strongest and the most absorbing of the affections. The Supreme himself has affirmed, that "it is not good for man to be alone." The AMATIVE (1) propensity disposes to the peculiar affection existing between the sexes. Above this organ is PHILOPROGENITIVENESS (2), which is cognizant of the affection subsisting between parents and children, and affords those pleasurable sensations which parents in general, but the mother in particular, feels the full force of. Above this is the organ of INHABITIVENESS (3), which induces a love of home and country. The home, rendered happy by connubial affection and the recreations of Philoprogenitiveness, is the chief solace of man's sublunary existence. On each side of Philoprogenitiveness is COMBATIVENESS (5), and on each side of Inhabitiveness is ADHESIVENESS (4). Again, the harmony of the locality, in the association of home and friendship, strikes us as remarkable. And when we have children, whose defenceless state not only requires care and watchfulness, but frequently the protecting power of resolute courage, the locality of Philoprogenitiveness and Combativeness is equally remarkable. In a state of celibacy, the female is retiring and unassuming; but no sooner does she become a mother, than a new feeling seems to put forth its power and take possession of her. She guards her young charge with the most tender and unwearied solicitude. Her weakness seems all lost in the infant, and physical power becomes associated with parental love, so that, if an attack were made upon her infant charge, though the aggressor might be possessed of herculean strength, she would resist even to the death. It is Combativeness which enables the otherwise timid female to stand up in defence of the object of her love—preventing the tyrannical, so far as her energy can reach, from smiting with the fist of wickedness. The superintending power of this group is SELF-ESTEEM (10), supported on each side by LOVE OF APPROBATION (11) and CAUTIOUSNESS (12). Cautiousness again appears to superintend SECRETIVENESS (7), ACQUISITIVENESS (8), and DESTRUCTIVENESS (6), which are all beneath it. This closes the group of the inferior propensities. Self-Esteem seems indispensable in the government of this group; he who loses self-respect has nothing to interpose in the regulation of his appetites. The Love of Approbation is well associated with Self-Esteem. It operates as a check against arrogance, pride, and selfishness, while it at the same time tends to prevent Acquisitiveness from becoming mercenary, and Secretiveness from becoming evasive. In the acquisition of wealth, for the double purpose of obtaining our subsistence now, and providing for it when old age impairs both our physical and mental energies, Acquisitiveness becomes eminently useful. Cautiousness shows its proper application, Secretiveness imposes discriminative prudence, and teaches us the proper regulation of our Acquisitiveness, and thus there is a check and a balance throughout the whole system. Even Destructiveness itself cannot be dispensed with. The path to excellence is beset with difficulty and danger, and requires the physical energy which this organ imparts, to rise superior to and overcome it.

Phrenology being thus illustrated—the three regions of the head thus exhibiting different powers—we may now affirm that our proposition has been established, that all the faculties are useful, and the position of the organs a proof of the truth of the science. It is education which must direct the whole organization. It is education which must train the noble powers with which God has endowed us: the mode of education we shall refer to as we proceed.

GEOGRAPHY.

CHAPTER II.

INTRODUCTION.—ON THE ASTRONOMICAL RELATIONS OF THE GLOBE, AND ON GEOGRAPHICAL NOMENCLATURE.

THE science of modern astronomy exhibits the earth on which we live, in a very different light from that by which it was viewed by its early inhabitants. Instead of the land being a vast plain, surrounded on every side by the sea, the sky stretched over it like a curtain, and the whole bounded by a bottomless abyss of impenetrable darkness—an opinion which was entertained by almost all the ancient nations—our earth has long since been proved to be a *globe* by many irresistible arguments, but chiefly by the fact, that its circumnavigation is now looked upon as a feat of very ordinary occurrence.—See fig. 1.

Instead, also, of this globe being considered the most important part of the works of creation, and the fixed centre around which the whole universe revolves every twenty-four hours in unceasing regularity, it is now proved to be a mere speck among myriads, a unit—perhaps a very insignificant unit, insignificant at least as to size and external grandeur—among millions of millions of globes of every size, and every degree of splendour and magnificence. It is also proved to be one of a small family of globes, or planets, which revolve at various distances, and at different velocities, around the sun;

J. W. Lowry fculp.

from this orb it occupies the third place as to distance, and revolves around him in 365¼ days, which is called a year. How humiliating the thought, that our earth is of no more comparative importance among the countless worlds which occupy the unfathomable regions of space, than a grain of

Fig. 1.—View of the World from the Planet Mars.

dust floating in the passing breeze, or a grain of sand on the sea-shore! With what horror would such an idea have flashed on the mind of the ancient philosopher, to whom the earth appeared the grandest effort of creative power! But are we, in thus acknowledging the insignificance of our planet, to be struck dumb with apathy and dismay, and to overlook the infinite wonders of creation, as exhibited even on this small globe on which our present lot is cast? No! It is to us of the greatest importance; it is destined to be the scene of our present joys and our sorrows, of our pleasures and our pains; it is in our own power to make it yield roses or thorns, to make it resemble a paradise or a hell! And as the higher we ascend among the works of God, our views of the infinity of creation are the more expanded; so the lower we descend among the minutiæ of these works, the more are we lost in wonder at the infinitude of their minuteness, and at the beautiful adaptation of circumstances to the wants of the most insignificant animalcule which can be discovered with the microscope. Although views, then, of the scenery of the heavens are best calculated to expand and elevate our ideas, yet there is no department in natural science which is not pregnant with information excellently fitted to purify our minds from the stains of our animal natures, and fill them with enlarged and ennobling sentiments; even the study of geography—a description of the various localities of the globe, as suited for the abode and civilization of mankind—may be made subservient to this end.

As we have already stated, the globe we inhabit is one of a small family of planets which revolve round the sun as their common centre, and are therefore called the *solar system.* This solar system itself is merely a unit in space, which, as far as the most powerful telescope can penetrate, is filled with myriads of orbs and systems, circling and encircling one another. The vast number of *fixed stars* which are visible to the naked eye, are so many suns and centres of revolution around which countless planets may revolve; and when we reflect that these multitudes of suns and systems are but a speck among the wonders of creation, the eyes become dim, and the mind is lost in the contemplation of the universe as a stupendous whole!

The earth revolves round the sun in an orbit of a somewhat *oval* shape, the sun being placed not exactly in the centre, but rather nearer one end than the other; the mean distance of the earth from the sun is 95,173,000 miles. In its orbit round the sun, the earth is attended by a moon, revolving round it in 27 days 8 hours, or in what is called a lunar month. The earth is 24,000 miles in circumference, and its surface is calculated at 197 millions of square miles; but, compared to the size of the sun, it is in the proportion of a pea to a globe of two feet in diameter.

The earth is surrounded by an atmosphere which exerts a pressure of about 15 lbs. on every square inch of its surface, and which diminishes in density in a duplicate ratio as we ascend from the earth's surface, till, at the distance of 45 miles, (or 40 miles above the tops of the highest mountains,) it must become so attenuated as to be almost imperceptible, and this distance, therefore, may be set down as the highest limit to which it extends. From the sun the earth derives its light and heat, its summer and winter, its day and night; but were it not for the atmosphere which surrounds it, the advantages it derives from this luminary would be but slight. Without an atmosphere, there would be no reflection of light and heat; every object on which the sun's rays of light did not strike directly, would be in total darkness, and the rays of heat being reflected by the earth back into space, an excessive cold would constantly prevail. The atmosphere, then, is the great recipient of light and heat, both retaining the heat which is reflected back from the earth, and intercepting and reflecting the direct rays of the sun—re-reflecting and multiplying them to such an extent, as to produce those scorching heats which are so oppressive within the tropics. The cause of the increase of cold by every increase of altitude, is solely owing to the greater rarity of the atmosphere the higher we rise above the level of the sea; what other cause *can* be assigned for those eternal snows which cover the tops of the Himmalayas under a vertical sun?

The figure of the earth is not a perfect sphere, but is what is called an *oblate spheroid,* being somewhat flattened at the poles, so that its longest diameter is rather above 7,925½ miles, and its shortest nearly 7,899 miles, making a difference of about 26½ miles, or a flattening of about 13¼ miles at each pole. This result is considered to have been produced by the action of centrifugal force upon the globe, before it was in a sufficiently hardened state; and it is illustrated by whirling a ball of soft matter, such as soft clay or putty, round an axis, when it will be seen to assume this shape. The mean density of the earth is five times greater than that of water; that is, this globe is equal in weight to one, five times the size, composed of water; and the interior of the earth is double the density of the rocks, &c., composing the surface. From the temperature increasing in a certain ratio as we penetrate into the earth, it is considered that its interior is composed of a molten mass, covered by an external hardened crust about 800 or 1,000 miles thick, and that the action of this fluid incandescent mass gives rise to the phenomena of earthquakes and volcanoes. The annexed diagram represents a small part of a section of the earth's crust: the dark line, A B, represents a thickness of ten miles, the depth to which man has explored; the points, *m, m, m, m,* indicate the altitude of the highest mountains; the depth of the sea is shown by the openings, *s, s,* at the ends of the dark line; the dotted line, *a, a, a,* represents the height of the atmosphere, —45 miles.—See fig. 2.

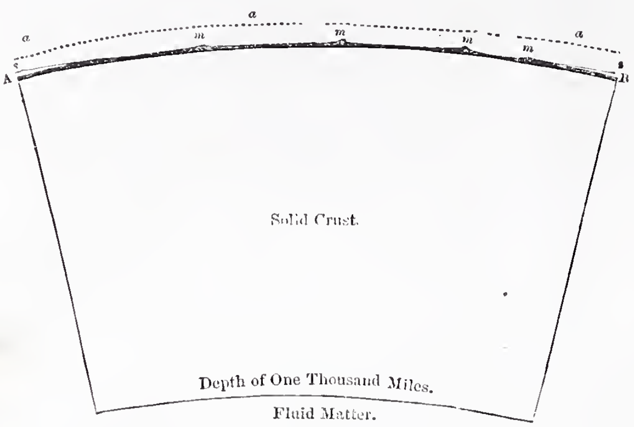
It requires but a glance at the above sketch to show forcibly with how infinitely minute a portion of the earth's crust we are in the least acquainted; three-fifths of the earth's surface are covered by seas, and another large portion by immense bodies of fresh water, by polar ice and eternal snows; so that, if we exclude the sandy deserts, morasses, &c., we scarcely leave one-fifth either accessible to the explorations of the geologist, or fit for the habitation of man and animals. Of what presumption, then, are those pseudo-philosophers guilty, who write and talk of the different strata composing the solid crust of the earth, the various animal and vegetable remains contained in these strata, the series of revolutions which our planet has undergone in its various stages of development, with as much certainty and assurance as if they had examined innumerable sections of the whole crust to the depth of 1,000 miles, and had laid the past history of the creation of the animal and vegetable kingdoms of nature open before them! Vain, silly man! to what ought thy writings and thy talkings to be compared, when one of the most exalted minds of thy species* aptly compared *his* splen-

* Sir Isaac Newton.

did acquirements, and *his* grand discoveries, to the prattlings of a child gathering pebbles on the sea-shore, with the vast ocean of unexplored science rolling before him ?

We have thus seen that the earth we inhabit is a *round globe*, that it revolves round its own axis every 24 hours, producing day and night, and accomplishes its journey round

Fig. 2.—Section of Solid Crust of the Globe.



its orbit in 365¼ days—a circumstance to which we owe the alternations of the seasons—and that it is also attended by a moon, revolving round it in 29½ days. The moon is an opaque body, shining only by the reflected light of the sun; she is 240,000 miles distant from the earth, and only $\frac{1}{56}$th part of its size. To the attraction of the moon we are mainly indebted for the tides of the ocean, it being high water in every place when the moon is in the meridian, or due south or north of that place.

All bodies are retained on the earth's surface by what is called the *attraction of gravitation*—an inherent property, with which all particles and masses of matter are endowed, of attracting each other. Were it not for this attraction, which produces a tendency in all bodies on the earth's surface to fall to its centre, everything on the earth, and under the earth nay, the very *earth itself*, would be separated into millions of atoms of infinite minuteness, and be all scattered in endless confusion through surrounding space.

From the fact of the earth being round, it is obvious that the people on the opposite side of the globe to us—*the antipodes*—must be standing with their feet to ours, and that the direction, which is *up* to us, must be *down* to them; hence we see that what we call *up* and *down* are merely relative terms, and that, as the surface of the earth at the equator is carried round at the rate of nearly 1,000 miles per hour, the direction which we call *up* is never one instant the same.

As an individual shut up in a railway carriage, proceeding at the rate of 60 miles per hour, is quite unconscious of the velocity at which he is moving, and it is not till he look out at the window, and see surrounding objects flying past in the opposite direction to which he is moving, that he becomes aware that he is thus hurried along; and as the banks of a river appear in rapid motion westward to a person sailing in a steam-vessel down the stream in an eastward direction, while he fancies the ship at rest; so we are carried round the globe, by its diurnal motion from west to east, at a velocity of nearly 1,000 miles per hour, or about 16 miles per minute, without the least consciousness on our part that we are in motion at all. Although, in the latter case, the optical illusion may be much more perfect than in the two former, it is exactly the same circumstance—the rapid motion of the earth from west to east—which gives rise to the apparent motion in surrounding bodies, and produces the apparent diurnal revolution of all the heavenly bodies from east to west. The revolution of the earth, then, round its own axis, which is accomplished every 24 hours, is called its *diurnal motion.*

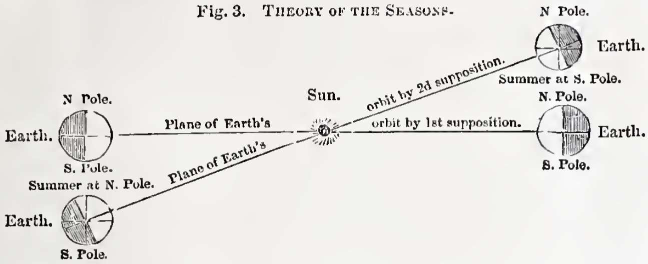
Suppose, in accordance with the common ideas of "*up*" and "*down*," that the earth, in its annual revolution round the sun, has its axis placed *perpendicularly*, the pole at the upper end being the *north*, and that at the lower end the *south*; and suppose the earth carried round the sun in this manner, so that a plane passing through the sun's centre would divide the earth into two equal halves; or, for the sake of clearer illustration, suppose the annual motion of the earth round the sun to be represented by hanging a round ball on an axis, in a circular aperture, at the centre of a round level table, this round ball to represent the sun; and by suspending from a thread another ball, and carrying it slowly round the outer edge of the table, so that one half would be above, and the other half below the surface of this table, this latter ball would represent the earth; the surface of the table, in this case, would represent the *plane* of the earth's orbit; the point of suspension by the thread the *north pole*; the opposite point the *south pole*, and the line of section of the ball by the surface of the table would represent the line of the *ecliptic*. In addition to the motion round the table, if the thread is slowly twirled round in the fingers, this would represent the *diurnal* or *daily revolution* of the earth. Instead, now, of a real table, let us suppose an imaginary one, and let the ball in the centre be luminous, or let it be a lighted candle; carry the ball round the circumference as before, and, at the same time, keep twirling it round its own axis by the thread, we would then have, so far, a tolerably correct idea of the motions of the earth. But if the earth revolved as we have supposed, on the same plane with the sun, having its axis at *right angles* or *perpendicular* to this plane, then we would have no alternation of the seasons, no variation in the length of the day and night; the winter in Britain would be hotter than the summer, from the earth being in reality nearer the sun in its orbit, at that period of the year, than in our summer; and the sun would rise exactly at six a.m., and set at six p.m., from day to day, from week to week, and from year to year, for ever: we would have none of those agreeable vicissitudes of the seasons which we now enjoy; the equatorial parts of the earth would be scorched by the never-ending heat of a vertical sun, while extensive regions towards the north and south poles would be abandoned to everlasting ice and sterility; some regions, again, situated in an intermediate position, would be blest with a perpetual spring, but which would then be so monotonous and cheerless, as completely to lose its present charms. An all-wise Creator, however, in carrying out that beautiful variety and harmony which the most minute as well as the most stupendous of his works display, had recourse to a simple and effective expedient to produce that endless change in the length of day and night, and that perpetual alternation of the seasons, which are so grateful and beneficial to all animate creation.

By the earth's oval or elliptic orbit round the sun, passing a little *above* this supposed level plane at one side, and a little *below* this level at the opposite side, our welcome variety in the length of day and night, and our change of seasons, are effected. By having recourse to our simple illustration already adduced, and by supposing our imaginary table, around which the ball representing the motions of the earth is carried, to be tilted off the level—raised a little at one side above its former level, and as far depressed below it at the other side—then, by carrying the ball round the lighted candle in this new direction, it will immediately be apparent, that when it is in that portion of its orbit *above* its former level, the lower end, which represents the south pole, will be illuminated, and the upper end, representing the north pole, darkened. When the ball is in the opposite side of the orbit, that is, *below* its former level, the reverse will take place—the north pole will be illumined, and the south darkened. When, again, the ball is midway between these two opposite ends, it will be

exactly at its former level, both poles will be equally illumined, and the rays will fall at right angles to the centre of the ball.—See fig. 3.

The above explanation is briefly expressed in technical language, by saying, that the earth's axis is somewhat *inclined* to the plane of its orbit round the sun; and by fixing this fact and the above illustration in the mind, we have the key to the explanation of the changes of the length of our

Fig. 3. Theory of the Seasons.



days and nights, and of the endless alternation of our seasons. When the earth is at its greatest height *above* the sun's imaginary *level*, if we may so speak, it is midwinter at the north pole, and midsummer at the south; when at its greatest depression *below* this imaginary level, it is midsummer at the north pole, and midwinter at the south; and when the earth is on our imaginary level with the sun—that is, midway between the points of extreme altitude and depression, which happens twice during each revolution round its orbit—the period of the year is midway between summer and winter, and the days and nights are equal: this, as we have said, occurs twice a year, and is called the *vernal* and *autumnal equinoxes*.

Before proceeding to describe the different divisions of the earth's surface, it is necessary to give a brief description and explanation of the principal terms and technicalities of geographical science.

For the sake of correctness of description, clearness and brevity of explanation, there are a number of technical terms employed in geography, as well as in every other science; and unless these are thoroughly comprehended, unless it is understood what is meant by such terms as latitude, longitude, bay, gulf, isthmus, peninsula, &c., the language of geography will be to the student an unmeaning jargon. Of such consequence, indeed, is a knowledge of the nomenclature of any science, in enabling the learner to become master of his subject with ease and rapidity, that the time occupied in committing its technicalities to memory is well spent, and the best and most useful preliminary process in which he can be engaged.

The following explanations, then, ought to be correctly understood, and carefully remembered, as otherwise we cannot advance a step in geography, read a simple book of voyages or travels, nor even a common newspaper, with advantage.

To mark the relative positions and distances from any point, or from each other, of the different portions of land and water on the earth's surface; to denote, also, the relative locality where any spot is situated, as well as to point out the probable climate and temperature which we may expect to find in any given place, every map of the world, or of any portion of it, is marked out with a number of artificial or imaginary lines.

We have, first, the "*equinoctial line*," or line of the equator, often also called, in familiar language, "*the line*." The *equinoctial* line* is an imaginary line, encircling the middle of the globe at an equal distance from both poles, and dividing the earth into two equal portions, called the *northern and southern hemispheres*. It is called *equinoctial*, because, when the apparent position of the sun is in that line, the day and night are of equal length.

* Recurring to the above illustration, the equinoctial line is the *plane* of the earth's orbit when on the supposed level with the sun, which happens twice during every revolution round its orbit.

Mathematicians divide every circle, large or small, into 360 equal parts, which they call *degrees*; every degree is divided into 60 *minutes*, and every minute into 60 *seconds*, and so on; symbolically expressed thus: ° = degree, ′ = minute, ″ = second, ‴ = third, &c.; and if we wished to express the latitude of London—fifty-one degrees, thirty minutes, forty-eight seconds, north—we would write it thus: 51°, 30′, 48″, N. Lat.

The equatorial line or circle round the globe is, therefore, divided into 360 degrees, and, by actual measurement, one of these degrees is found to contain 69½ English miles. By fixing upon any point on this encircling line to begin counting from, calling it 0, the distance of all parts, east and west, on this line can be easily ascertained by knowing how many degrees they are from the starting point. All distances eastward and westward on the globe are measured by the length of a degree on the equatorial line; hence these distances are called degrees of *longitude* because they are the measurement of distance by the *length* of this line; if the distance extends eastward, it is called *east longitude*; if westward, *west longitude*. Since, then, the whole circle contains only 360°, it is obvious that no place on the earth's surface can be farther distant, east or west, than 180°, or the half of 360°.

By beginning at the starting point, 0, and marking the different degrees of east and west longitude on the equator, and then by drawing straight lines from these to the poles, we thus have the *meridian lines* of longitude into which the globe is artificially divided—lines which are indicated in the heavens, in every locality, by a straight line joining the zenith, or the point in the heavens perpendicularly over our heads, with the sun at mid-day, and prolonged to the horizon north and south.

Our starting point, 0, from which we begin to measure distances on the equator, is called the *first meridian*, and is quite arbitrary, it being a matter of no moment where we begin to measure, provided it be fixed and well known. Most nations begin counting longitude from the principal observatories of their respective countries. In Britain, and in several other countries, the observatory of Greenwich is adopted; in France, that of Paris; while in Germany, the island of Farroe is fixed as the first meridian.

When any place is said, therefore, to be so many degrees of east or west longitude from Greenwich, it is meant that this place is so many times 69½ miles east or west from the meridian of Greenwich, which in Britain is the first meridian.

The term *latitude* literally means *breadth*, and distance north or south from the equator is called *latitude*, because it is the measurement of breadth from that imaginary line. As already mentioned, every circle is divided into 360°, and if the first meridian, or the meridian of Greenwich, be extended round the globe, intersecting the equator, as it must do, at right angles, it follows that it also must contain 360°, the half of which, or the distance from the north to the south pole, must be 180°; and one-fourth, or the distance from the equator to either of the poles, must be a quarter of a circle, or 90°.

When any place, then, is said to be so many degrees of north or south latitude, it is meant that it is so many times 69½ miles from the equator. These lines of latitude are parallel to the equator; hence they are called *parallels of latitude*. But since the meridian lines of *longitude* all meet at the poles, the distance between them must be less the farther away from the equator; the standard measure of a degree of longitude, therefore, must refer to the length of a degree on the equator, as otherwise these degrees would become shorter and shorter the farther from the equator and the nearer the poles, so that we would have a different measurement of a degree of longitude for every change of a degree of latitude. The lines of latitude, on the other hand, being parallel, a degree of latitude can be measured on any portion of the globe.

On two days only during the year does the apparent daily course of the sun coincide exactly with the equinoctial line, and this happens at what is called the vernal and autumnal

equinoxes, when day and night are equal. During the intervening periods, the sun appears to travel so many degrees north, and so many degrees south, producing the changes of the seasons, and the variation in the length of day and night —a circumstance, the cause of which was above explained by the course of the earth's orbit rising above the plane of the sun, as it were, at one period of the year, and sinking below it at the opposite period, or, as is technically expressed, by the earth's axis being *inclined* to the *plane* of its orbit.

If we could see the stars during the day, so as to enable us to mark the sun's course among them, it would be found that he is constantly shifting his relative position; that a star which appears a little eastward of the sun to-day, would, in a few days more, pass the sun and be seen to the westward of that orb, and that thus the sun is pursuing a *backward* course among the stars, completing a whole round of the heavens, backwards as it were, in a year. This annual path of the sun is denominated the *line* of the *ecliptic*,* because it is when the moon crosses this line in her orbit that eclipses happen.

If the apparent daily course of the sun, then, were marked out in the heavens by a golden belt, on the day of the vernal or autumnal equinox, this belt would represent the *equinoctial line*. If a mark were put in the sun's place in the heavens every day at noon for a whole year, this dotted line would make a complete circle of the heavens, shifting its relative position daily; it would intersect the equator at two opposite points, would reach 23½ degrees north of that line on one side of the circle, and the same distance south on the opposite side, and this dotted line would represent the *ecliptic*.

Again, if the apparent path which the sun describes, during the longest day, were traced in the heavens, when he is at the extreme northern point in the ecliptic, the path thus marked out would indicate the artificial line called the *tropic* of *Cancer*; and if the sun's apparent course were traced in the heavens during the shortest day, or when he has arrived at his extreme point in the ecliptic southward, this course would indicate the *tropic* of *Capricorn*. The former of these lines is 23½ degrees *north*, the latter 23½ degrees *south* of the equator, and all the countries situated between these lines are said to be *within* the *tropics*. These lines are called the *tropics*, because the sun, in his apparent course in the heavens, never crosses them, but appears, when he arrives at them, to *turn* back.

The portion of the earth included between these two lines is called the *Torrid Zone*, from the great heat which almost always prevails there. The days and nights are of nearly equal length through the whole year; the sun rises nearly due east, mounts upwards right overhead, and sets nearly due west; his rays, therefore, fall almost perpendicularly at mid-day, (which is the cause of the intense heat,) and at that hour the inhabitants have no shadow. The only change of seasons which is there experienced, are the wet and the dry seasons: during the former, the earth is deluged with great torrents of rain; during the latter, it is scorched and burnt up by the piercing rays of a vertical sun. It is in that portion of the earth where the dreaded hurricane, the fearful tornado, and the devastating earthquake exert their greatest fury, and produce the direst effects. There, too, do the animal and vegetable kingdoms exist in greatest perfection;—the most luxuriant herbage, the most enormous trees, the most delicious fruits, animals of the largest size, birds of the gayest plumage, and reptiles of the most venomous species—all luxuriate in this clime of the sun. But there, alas! is man seen in his lowest stage of deterioration—there does he exhibit all his animal propensities in the most exaggerated form, while his spiritual and moral nature seems in a proportionate degree effaced.

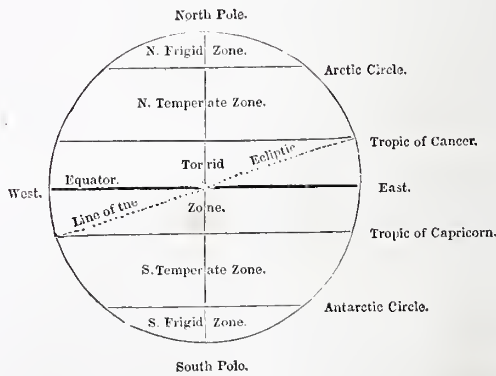
Parallel to, or concentric with, the tropics and equator, and at the distance of about 23½ degrees from each pole, we have other two artificial or imaginary circles which surround the globe: the one on the northern hemisphere is called the *Arctic* or *Northern Circle;* the one on the southern, the *Antarctic Circle.* The portions of the earth included between these two circles and the poles, are called the *North* and *South Frigid Zone*, respectively. In the North Frigid Zone, the only appearance of vegetation are a few stunted shrubs and mosses, the inhabitants are few in number, thinly scattered, and of very diminutive stature; while the South Frigid Zone is entirely destitute of a trace of man, and plants and animals, if any exist, must be extremely few. Both the North and South Frigid Zones are in darkness for a part of the year, for another part there is constant twilight, and for a third part the sun never sets; towards both poles the regions consist entirely of frozen wastes and impassable barriers of ice; at each pole the year consists of a single day and a night, each of six months' duration, the sun appearing to move only in the line of the ecliptic, and the stars to retain a fixed position.

Those portions of the globe included between the tropics and the Arctic and Antarctic circles, are denominated, respectively, the *North* and *South Temperate Zones.* Although the north and south portions of these zones partake more or less of the nature of the adjoining torrid or frigid zones, still the greater parts of these extensive regions enjoy a mild and genial climate; they are blest with the pleasing vicissitude of spring, summer, autumn, and winter, succeeding each other at different periods of the year; they produce those crops and other necessaries best suited for man in his most perfect condition on earth, who is here more distinguished for intellect, intelligence, and industry, than on any other portion of the earth's surface.

The people who live north of the *tropic* of *Cancer*, have the sun always due *south* at mid-day; those who live south of the *tropic* of *Capricorn*, have the sun due *north* at mid-day; while those who live within the tropics, have the sun at noon due north during one period of the year, and due south during another period; and twice every year they have the sun at mid-day in their *zenith*, or in that point in the heavens directly over their heads, so that at these periods they have no shadow.

Of these zones, the torrid zone is the largest, being about ten times the size of either of the frigid zones, and nearly one-third larger than either of the temperate zones. (See fig. 4.)

Fig. 4.



A *Map* is a representation of the whole earth, or of a part of the earth, on a flat surface; and since it is impossible correctly to represent a globe on a flat surface, it therefore follows that all maps are more or less inaccurate; but when the portion of the surface of the globe represented is but small, the inaccuracy is trifling. The *top* of a map is *North;* the *bottom*, *South;* the *right-hand side*, *East;* the *left-hand side*, *West*, unless when otherwise expressed.

Nearly one-third of the earth's surface is *land;* two-thirds, *water.* The land is divided into *Continents* and *Islands;* the water, into *Oceans*, *Seas*, *Gulfs*, *Lakes*, and *Rivers.*

A *Continent* is a great extent of land, not disjoined or interrupted by a sea.

An *Island* is a tract of land wholly surrounded by water.

* The line of the ecliptic is in reality the *plane* of the earth's orbit.—See fig. 3.

A *Peninsula* is a portion of land connected with a continent by a narrow neck, but nearly surrounded with water.

An *Isthmus* is a narrow neck of land by which two continents are connected, or by which a peninsula is united to the mainland.

A *Cape, Promontory, Point, Headland, Head, Mull, Foreland, Naze* or *Ness*, is a portion of land jutting out into the sea beyond the common shore.

A *Plateau* or *Table-land* is a tract of level land elevated above the surrounding country.

A *Prairie, Savannah, Plain, Steppe* or *Pampa*, is an extensive tract of land, mostly level, destitute of trees, and covered with tall coarse grass.

An *Ocean* is a large uninterrupted extent of sea.

A *Sea* is a portion of salt water of less extent than an ocean.

A *Strait* is a narrow neck of water joining two seas, or connecting a sea or lake with the ocean.

A *Sound* is a strait so shallow that it may be fathomed.

A *Channel* is a wider and larger passage between two seas, than a strait.

A *Gulf* is a portion of water almost surrounded by land, or a recess of the sea or ocean into the land, from the general line of the shore.

A *Bay* is a bend of the sea into the land, with a wider neck or opening than a gulf.

A *Frith* or *Estuary* is a narrow stripe of sea stretching inland, to receive the waters of some large river.

An *Archipelago* is a sea containing a cluster of islands.

A *Road* or *Roadstead* is anchorage ground for ships near a harbour.

A *Cove* is a small gulf; a *Creek*, a small arm of the sea.

A *Lake* is an extensive collection of water contained in a cavity or hollow of the earth.

HORTICULTURE.

CHAPTER I.

OUTLINE OF HISTORY OF HORTICULTURE, AND PLAN OF THIS DISSERTATION.

GARDENING differs from farming, in procuring from the soil the luxuries more than the necessaries of life. Its operations, moreover, are conducted on a comparatively small scale, and the labour employed is that of men only, and not, as in agriculture, of men and horses. The most usual form of gardening practised in this country, is the cultivation of such plants as come naturally to maturity in the open air, and these plants may be divided into three classes—vegetables, fruits, and flowers. With increasing luxury, however, we have ceased to be content with this; and we now rear under glass, amid an artificially heated atmosphere, the fruits and flowers of both tropical and arctic countries, particularly those of the former. This is done to a very different extent in different gardens, and different classes of gardens, but it is a very poor garden that does not contain at least a cucumber frame.

Besides this main object of producing a supply of vegetables and of fruit for use and luxury, and of flowers as ornaments, a garden always has been, and still is, considered as a place of recreation. One of the earliest gardens of which we have any account is that of Solomon, and it contained aviaries and a seraglio—this latter being, it has been inferred, intended, partly at least, as a temple in which to worship some deity corresponding with the Roman Venus, and of whom some one of his numerous wives was a votary. In the ancient Hebrew gardens, a very prominent place would appear to have been assigned to cucumbers, gourds, melons, and other succulent vegetables, which the hot and dry climate of Palestine rendered particularly desirable. Next in importance came onions, garlic, and the other alliaceous plants, that probably were then, as they now are, in the Peninsula, a main source of the daily food of the populace; and after them, in importance, were ranked certain condiments and spices, as aniseed, coriander, &c. Besides these, Solomon had in his garden apples, figs, vines, timber trees, lilies, roses, and a collection of other plants, illustrative of that science of natural history to which the royal philosopher was so much attached.

The Hebrews were acquainted, if not exactly with the use of guano, at any rate with the use of what is exactly analogous to it—the excrement of the pigeon. Oriental customs rarely change; and at the present period this manure is extensively employed in the East, particularly to promote the rapid growth of succulent plants, such as the gourds and melons. No plants, we may remark, produce so much food in so short a time as those do, provided the soil in which they grow be sufficiently rich. There is every reason to believe that the "fourth part of a cab of doves' dung," mentioned in 2d Kings as selling, during the famine, for the great price of "five pieces of silver," was purchased at so extravagant a rate in order to stimulate the vegetation of these plants.

The cultivation and the use of flowers attained, from a very early period, both among the Oriental nations and the ancient Greeks, a very considerable prominence. Flowers were much used; they were spread upon the altars of the gods, tables in private houses were covered with them, they were bound around the brow of the returning conqueror, and even the philosophers wore wreaths of flowers around their heads.

The earlier legislators were more given to interfere with small matters, and to make laws in cases where it seems difficult to find a reason for so doing, than their modern successors. Two very remarkable restrictions were put upon vegetables by the Greeks. Solon positively prohibited pregnant women the use of coleworts, and Pythagoras forbade any of his followers to eat broad beans. The Pythagoreans, it will be remembered, used no animal food; and the reason why their founder put the ban upon the broad beans was, that he suspected an affinity between their structure and that of flesh. Beans were, he said, the first cousins of man. The colewort has, and almost in our own day, disappeared from cultivation, and we cannot pronounce upon its properties. But the researches of the modern organic chemists have discovered that, as far as chemical constitution is concerned, beans really are "first cousins" to man, and that they contain a very large proportion of substances analogous to the blood, flesh, &c., of animals. It is surely not possible that a high state of civilization and learning in physical science, may have once existed in this world, and passed away without leaving a history behind it; and that the idea of Pythagoras, relative to the nature of the bean, was a tradition that had come down from a primeval Liebig, whose very existence and name have been forgotten in the roll of innumerable centuries.

The ancient Romans were essentially an agricultural and country-occupying people, and consequently bestowed much attention upon gardening; and when we come to the times of the empire, we find very extensive and magnificent ones. Still both earlier and humbler attempts were common. According to Pliny, a countryman likened his garden to a flitch of bacon, as being always ready to cut and come at, or to a salad as not requiring cooking and as easy of digestion. We have a pretty exact knowledge of the manner in which the Romans cultivated their gardens, and their horticulture is characteristic enough of their superstitious and morose national character. The tutelary deity of the Roman garden was Pan. Some of the garden operations were performed in the waning, others at the increasing of the moon, and at no other time. When the turnip crop was attacked by the fly, a woman, barefooted and with her hair unbound, was made to march around the turnips to drive them away. The man who sowed turnips was directed to do so naked. Although, as just mentioned, a woman was considered able to scare away the turnip fly, still the members of the fair sex were carefully kept out from that part of the garden where the cucumbers and gourds were grown, inasmuch as a woman's handling was held to check the increase of these vegetables.

The following is a list of the fruits and vegetables which we know to have found a place in Roman gardens:—Apples, pears, quinces, services, medlars, peaches, apricots, nectarines, almonds, cherries, plums, olives, grapes, figs, mulberries, straw

berries, nuts, walnuts, chestnuts, cucumbers, gourds, melons, cabbages, beans, peas, turnips, carrots, parsnips, skirrets, beet, radishes, asparagus, onions, garlic, endive, lettuce, chicory, mustard, mushrooms, parsley, fennel, chervil, and a variety of other pot herbs. They likewise kept in their gardens bees, and also a breeding place for snails, an animal which modern taste does not approve of for the table. When we come down to the times of the empire, we find the Romans using forcing-houses; and it is on record that Tiberius was very fond of cucumbers, and that his gardener contrived to give him a supply all the year round.

When the Romans obtained possession of Britain they introduced their arts, and amongst the others, the art of gardening. Tacitus remarks that the soil and climate were perfectly adapted for all the Roman plants, save the vine and olive, and one or two more. But it was subsequently found that the vine does well enough in the southern part of the island, and during the middle ages several extensive vineyards were formed, not one of which has now an existence. We believe the last was at Arundel, and that the cellars there, last century, contained many hogsheads of claret made from its produce.

The Roman system of gardening was probably banished from this island by the Saxon invasion and conquest. The Saxons were a nation of rovers, at least for a long period, and, moreover, they were great consumers of animal food, and probably were altogether careless of any articles of diet save corn and flesh. As they became settled, however, gardening revived, the first revivers being the monks. These would follow the directions of the Roman writers upon gardening that had come down to them—Cato, Varro, Pliny, Columella, and perhaps others now lost. But it may be doubted whether the system of gardening introduced by the monks equalled that of the Romans, save perhaps in the culture of some of the commoner fruit trees, as apples and pears. The earliest record that has occurred in the course of our reading of this revived gardening, relates to the garden of Icolmkill, in the Hebrides, or Western Islands. "On a plain," writes Dr. Walker, the historian of this part of the empire, "adjoining the gardens of the abbey, and surrounded by small hills, there are vestiges of a large piece of artificial water, which has consisted of several acres, and been contrived both for utility and pleasure. Its banks have been formed by art into walks, and, though now a bog, you may perceive the remains of a broad green terrace passing through the middle of it, which has been raised considerably above the water. At the place where it has been dammed up, and where there are the marks of a sluice, the ruins of a mill are still to be seen, which served the inhabitants of the abbey for grinding their corn. Pleasure-grounds of this kind, and a method of dressing corn still unpractised in these remote islands, must, no doubt, have been considered in early times as matters of high refinement." We have the authority of the late distinguished horticulturist, Neil, for stating that several superior kinds of apples and pears are still to be found in the neighbourhood of old monastic establishments. He instances the Arbroath "orlin," a variety which we are personally unacquainted with, but which, he says, is an apple found abundantly around the ancient monastery of Aberbrothwick, or Arbroath.

One of the old chroniclers, describing the peculiarities of the year 1257, states it to have been a very backward season, and observes that "apples were scarce and pears scarcer, and that cherries, plums, figs, and all sorts of shell fruits were almost quite destroyed." Before this period, however, we should state that David I. of Scotland had, according to Chalmers, a garden at the foot of the Castle Rock at Edinburgh. James I. (of Scotland) seems to have been an enthusiastic gardener, and to have endeavoured to spread a taste for it among his subjects. James III. is supposed to have had a garden in the valley beneath his usual residence of Stirling Castle. The Regent Murray had one in Edinburgh, and the remains of one still exist around Falkland Palace. There was probably a pretty large one adjoining to Holyrood, extending perhaps from the Palace to the large trees by the Duke's Walk. Indeed, if the vicinity of other palaces and large houses be carefully examined, traces of a garden may usually be found. In a recent visit, for instance, to the ruins of Craigmillar Castle (near Edinburgh), we noticed distinct remains of one, in which, probably, during the few moments of happiness her destiny allowed her, Queen Mary of Scotland took pleasure.

But while, during the middle ages, gardens were attached to monasteries, to royal palaces, and probably also to the houses of the great feudal lords, they cannot have been either common, extensive, or well stocked. Some of the vegetables indispensable to us—as, for example, the potato—were altogether unknown; and notwithstanding the immense number of servants the great feudal lords were in the habit of keeping, one gardener was sufficient for the establishment of the great and almost regal Duke of Northumberland. Indeed, previous to the sixteenth century, cabbages and salads, and pot herbs, together with pease and other vegetables, were imported to this country from Holland.

It is in fact to the Low Countries that we must look for the origin of modern gardening; and to the great attention paid by the Dutch to the culture of vegetables and flowers, must unquestionably be ascribed the great superiority that we possess in this respect over our mediæval ancestors. And yet it is difficult to assign a cause for this. But it is certain, that, as far back as the twelfth century, the Dutch were remarkable for their love of flowers; and, in fact, it would seem that nearly at that distant period we must ascribe to them the creation of that taste for florist's flowers, as they are called, which has only as yet extended among the higher ranks of the community.

By the sixteenth century, the Dutch possessed every plant that we now have, save the pine apple, not then introduced from the West Indies. It was probably to the close communication between Holland and Britain that the very sudden change for the better which took place in English gardening must be ascribed. "Gardening," says Fuller, writing in 1660, "was first brought into England for profit some seventy years ago, before which we fetched most of our cherries from Holland, apples from France, and hardly a mess of rath ripe pease but from Holland, which were dainties for ladies, they came so far and cost so dear. Since then gardening hath crept out of Holland to Sandwich, Kent, and thence to Surrey, where, though they have given £6 an acre and upwards, they have their rent, live comfortable, and set many people to work."

It may not be uninteresting here to dwell a little upon the diet and health of our mediæval forefathers, as illustrative of the very great importance of gardening.

There is a disease scarcely ever now seen upon land, and but rarely even at sea, called scurvy, which used to be one of the greatest scourges that humanity was afflicted with. It is produced by a diet in which vegetables (*i. e.* fresh vegetables, not corn) do not form a sufficient proportion. During the summer, our forefathers had a supply of vegetables and plenty of grass for their live stock. As they had neither turnips nor artificial grasses, they were obliged to depend for the winter food of their animals upon natural hay, which they only had in small quantities. Accordingly, in November (or blood month, as the Saxons called it), they slaughtered and salted their fat animals, in order that as much hay might be left as would serve to keep alive those whom they kept for breeding. Upon this salt meat and upon bread they subsisted until probably the following June. They might have a few kail and red cabbages, and perhaps the monks might store salsify and other roots, but if so, probably in very small quantities. As a general rule, however, fresh vegetables cannot be said to have formed any portion of the winter diet of our ancestors. The consequence was, that, during the latter part of winter and beginning of spring, the population was liable to be devastated by scurvy.

The older historians are continually describing the havoc committed at these seasons of the year by the scurvy. Still more recently, we are acquainted with the evil effects produced by this disease among bodies of men subsisting upon a diet in which fresh vegetables did not bear their proper share. We allude to what happened in the earlier history of our colonies, and to our ships at sea. As these things happened nearer to

our own time, and as our circumstances regarding them is more precise, we prefer alluding to these cases as illustrative of the terrible consequences of not employing vegetables all the year round, and consequently of the great value, and indeed absolute necessity, of the art of horticulture.

When the French first settled in Canada, they experienced such a dreadful mortality in winter, that they contemplated abandoning their settlement. So likewise did the British in Newfoundland. The first settlers at Hudson's Bay, all, or nearly all, died from scurvy; and, after repeated disastrous winters, it was at last pronounced to be absolutely impossible to pass the winter there. But about a century ago, having accidentally introduced vegetables into their diet, they became quite healthy.

Perhaps, however, the most terrible disclosure of the great mortality induced by scurvy may be taken from the history of our fleet, and the fleets of other nations.

Thus Vasco de Gama, who discovered the passage to India by the Cape in 1497, out of a hundred and sixty of a crew, lost a hundred by scurvy. Cartier, in his voyage to Newfoundland in 1535, describes what his men suffered as follows:—"With such infection," he says, "did the sickness spread in our three ships, that about the middle of February, of a hundred and ten persons that we were, there were not ten whole, so that one could not help the other—a most horrible and pitiful case. Eight were already dead, and more than fifty sick, and, as we thought, past all hope of a recovery. In such sort did the sickness continue and increase, that, by the middle of March, there were not three sound men left. Twenty-five of our best men had died, and all the rest were so ill that we thought they would never recover again, when it pleased God to cast his pitiful eye upon us, and send us knowledge of a remedy for our health and recovery." The first equipment sent by the East India Company consisted of four ships, commanded by Commodore Lancaster, and the crews numbered 480 men. They sailed in spring in 1600. By the time they reached the Line, the crews of three of the vessels were so cut down by scurvy, that the passengers had to do the sailors' work. By the time they got to the Cape, the sailors from the Commodore's ship had to go to the other three ships, who had by this thrown a quarter of their complement—dead of scurvy—overboard, to take in their sails, for the crew of the Commodore's ship was quite healthy. The fact was, that they had vegetables and the other three had not. This, perhaps, was the first indication of the true cause of the malady, which, however, still very extensively prevailed. Admiral Hosier, in 1726, commanded seven ships of the line, and actually buried all his crew twice over of scurvy. Lord Anson, in his memorable voyage to the western coast of South America, out of every five of his crew, lost four from scurvy.

At length, in 1772, Captain Cook set out on what proved a four years' voyage, with a crew of 118 men, and returned with only a loss of one man by disease. This distinguished circumnavigator took care that his crew had regular supplies of fresh vegetables. And from his day the cure, or rather the preventive for the disease, has been recognized.

Our channel fleet had, however, an attack, so late as 1795. The winter preceding the spring of this year had been uncommonly severe, and the vegetables about Portsmouth were nearly destroyed, and became very dear. Beef, too, had risen in price, and the Victualling Board only allowed fresh meat one day in a week. In April, scurvy made its appearance in every ship. Immediately fresh meat, oranges, and lemons were freely supplied, and as the season advanced fresh vegetables, and by May 31, 5,000 lbs. of salad were sent every day to the fleet, and the result was, that the disease almost at once disappeared. At the present day, the disease is absolutely unknown in our navy, and scarcely in our mercantile marine,

On land, indeed, it every now and then begins to break out in workhouses, prisons, &c., if the due supply of vegetable food be stopped; but as it instantly disappears when that supply is afforded, it never becomes severe, and scarcely any one now-a-days dies of scurvy produced by not eating plenty of vegetables in winter. To this end the general use of the potato has greatly contributed.

To return, however, to the history of gardening.

The modern system of gardening may be said to have originated in England under Henry VIII., and to have spread to Scotland some time later; the first Scottish garden of consequence being, perhaps, that of the Duke of Hamilton, at Hamilton. The garden of Henry VIII. was called Nonsuch. "In it," says an old writer, "there were groves ornamented with trellis wood, cabinets of verdure, and walls embowered with trees, with columns, and with pyramids of marble. Two fountains that do spout water—the one round, the other like a pyramid, on which are perched all over small birds, that spout water out of their bills." As to the manner in which this garden of Nonsuch was cropped, we have no means of judging, save from a report of a survey taken some hundred years after its formation. From this survey we learn, that it was divided into compartments by means of thorn hedges; that on one side was a kitchen garden, surrounded by a wall, fourteen feet in height, and in which were seventy-two fruit trees, and one lime tree; that in the other parts of the garden, there were a hundred and forty-four fruit trees, two yews, and a juniper tree, and that it contained a wilderness and a bowling-green.

During the same reign, Cardinal Wolsey had the gardens at Hampton Court laid out; and, indeed, we suspect that the labyrinth still existing there, is the original one. During the reigns of Elizabeth and James I., considerable attention was paid to gardening, and the gardens of Theobalds, (pronounced by the cockneys, Tibballs) Greenwich, Hatfield, and Holland House were laid out, and also, in all probability, some of the oldest Scottish gardens. Charles I. was a patron of horticulture, and his "Herbalist," as he was styled in the court language of the day, published the first complete and original treatise upon gardening that our language possesses. Previous, indeed, to the publication of Parkinson's work, there had appeared, in 1557, "Tusser's Five Hundred Good Points of Husbandry," many of which referred to gardening; in 1574, "Hill's Profitable Art of Gardening;" in 1594, "Platt's Garden of Eden;" in 1597, "Gerard's Herbal," and "Lawson's New Orchard and Kitchen;" and in 1623, "Gervase Markham's Country Housewife's Garden;" but the work of Parkinson is generally considered the first of our native horticultural publications that deserves the name of an original and complete treatise upon the subject. It is entitled "Paradisus Terrestris, or a garden of all sorts of pleasant flowers which our English ayre will admit to be raised up, with a kitchen garden of all manner of herbs, roots, and fruites for meate or sauce used with us, and an orchard of all sorts of fruit-bearing trees and shrubbes fit for our land, together with the right ordering, planting, and preserving of them, and their uses and virtues. Collected by John Parkinson, Apothecary of London. Dedicated to the Queen (Henrietta Maria), 1629."

Parkinson was acquainted with nearly all the vegetables at present cultivated, but it is evident that cauliflowers, celery, and potatoes were new to him. It is proper that the perusers of old horticultural works should be aware, that in them the word potato by no means corresponds with the esculent now so well known under this name. The potato of the older writers is a species of *convolvulus batata*, an esculent root that does not ripen in this country, but which used to be imported from Spain, and was apparently much relished in the sixteenth and seventeenth centuries. It is referred to by Shakspeare in the line—

"Let the sky rain potatoes and hail-kissing comfits."

Cromwell and Charles II., particularly the former, himself originally a country gentleman, were both patrons of gardening, and the art of horticulture flourished during their reigns. It is believed that some existing Scottish gardens, and many Scottish horticultural improvements, date their origin from the times of the Protectorate. It is said, that cabbages (meaning, we presume, hearting cabbages) were unknown in the northern part of the island, until introduced there by Cromwell's soldiery.

From that period down to the present, systematic treatises upon gardening have been numerous in our literature. One of these, and it is, we believe, a somewhat rare work, is now

lying before us, bearing the date of 1681, *i.e.* seven years before the Revolution. It is a treatise upon rural affairs in general, and bears the title of "Systema Agriculturæ, by J. W." This J. W. was John Worlidge. We pass over the parts relating to farming, sporting, &c.; but, perhaps, an abstract of the contents of this work, relative to the management of vegetables, may not be uninteresting, as giving a notion of our ancestors' mode of management in these respects, nearly two centuries ago.

It would appear that, in Worlidge's time, some doubts were entertained of the utility of vegetables altogether. "Never heard of such things in my young days," was, we suppose, the cry of our progenitors regarding them in generations back. Worlidge, however, is a stanch defender of all garden productions. "At such tables," he says, "where there is the greatest plenty, garden tillage is as acceptable as flesh meats, and if it be only a sauce, yet it helps to fill the belly."

Beans, in Worlidge's time, were sown between St. Andrew's day (*i. e.* Nov. 30) and Christmas, at the wane of the moon. The custom was to sow them broad-cast, but Worlidge recommends them to be sown in drills with carrots between them, to serve as an aftercrop. He was quite aware of two facts not generally known even yet. The pods should be cut off with a knife, not pulled, as is generally the case; and if a young plant be cut down before it forms pods, it springs up again, and yields a crop at the end of the season, long after the main crop is over. Worlidge's management of peas is exactly that followed now-a-days. He calls French beans codware, and gourds pompions, and he recommends the latter to be planted in ground richly impregnated with pigeons' dung. Artichokes would appear to have formerly received far greater attention than they now do. Asparagus was, with Worlidge, as it, is, indeed, almost universally a great favourite. He managed this vegetable as we do now, but he states that many consider it advisable to put rams' horns into the bottom of the trenches, "holding for certain, that they have a kind of sympathy with asparagus, which makes them prosper the better;" but this is referred to the "experienced." Worlidge knew also how to force asparagus.

Singularly enough, among the esculent vegetables, not the fruits, Worlidge reckons strawberries, and places them between asparagus and "cole flowers." His culture of them was somewhat peculiar. He grew them in the shade, and, if we understand him right, shifted them every two or three years. He top-dressed them with dried cow or sheep dung, obtained an autumnal crop by cutting away the earliest blossoms, and he possessed a variety distinguished by its very green colour, and by the fruit lying on the ground underneath the leaves.

He managed his "cole flowers" exactly as we do our cauliflowers and broccolis. The same may be said of cabbages and savoys. He blanched lettuces by covering them with a small earthenware pot. He cultivated beet, but sowed it broad-cast, and then transplanted it as we do cabbages.

Carrots are, according to Worlidge, "the most necessary and universal roots this country affords." As we before mentioned, he grew them between the drills of beans. Turnips he appears to have held in very small esteem. There is nothing peculiar in his management of parsnips, skirret, and radishes. "Potatoes," he says, "are very usual in foreign parts, are commonly eaten either buttered, or in milk, and it hath not yet been assayed whether they may be propagated in great quantities for food for swine or other cattle!" He speaks of propagating Jerusalem artichokes by seeds. These seeds must have been procured from Italy, as the plant seldom or ever flowers in this country. Onions, if necessary, he transplants, and is a strenuous advocate for the cultivation of tobacco at home.

Since the Revolution, two important changes have been introduced into gardening. The one of these is the employment of glass-houses artificially heated, in which to rear plants that do not agree with the outdoor temperature. The other is this—for a long time, gardens were divided into formal walks, and had usually clipt trees, statues, bowling-greens, &c. In the reign of Queen Anne, the natural style, as it is called, was introduced. This natural style consists in imitating landscape gardening upon a small scale. But as a garden is essentially an artificial production, the propriety of this may be doubted; and now that (thanks to Mr. Hay) we are acquainted with the scientific principles upon which the beautiful in form depends, a recurrence to the purely formal and artificial seems desirable.

Another revolution has been gradually taking place. A garden was for a long period the rich man's luxury only; and those gardens that are now attached to our great houses, are on a large scale; are provided with forcing-houses, hot-houses, and conservatories; are attended by a large staff of gardeners; and are necessarily kept up at a great expense. But there has gradually arisen a class who like to have a garden on a small scale; who desire to grow everything that comes to maturity in the open air in this country, and to have a number of hardy flowers. Such persons dispense with the complicated forcing-houses, &c., and manage it themselves with the occasional aid of a labourer. Where there is one garden of the former kind, there are a thousand of the latter. Yet all the dissertations on horticulture in Encyclopædias, &c., are adapted for the use of the possessors of the former kind, and not to assist him who wishes to manage a small garden himself.*

This present dissertation on horticulture is intended for the use of the occupier of the humble garden. The writer of it assumes that the reader is desirous of making and cultivating a garden containing an acre of ground; that he desires as abundant and continued a supply of fruit, vegetables, and flowers as can be procured in the open air, with the assistance merely of a cucumber frame, and he attempts to instruct the reader as to how to effect all this. Almost everything that he has noted down is the result of his own practical experience. He would, before proceeding to details, have enlarged upon the chemical and physiological principles upon which gardening is based; but these are the same as those upon which agriculture depends, and are fully treated of in this work, under the head AGRICULTURE.

AGRICULTURE.

CHAPTER III.

OUTLINES OF AGRICULTURAL GEOLOGY.

THE importance of a knowledge of geology to the agriculturist is very little appreciated. Any one who is acquainted with this science and with farming, can, upon merely glancing at a geological map of this or any other country, at once determine its agricultural capabilities, and even describe the mode of farming and cropping that is sure to be followed upon it. The value of this previous knowledge either to an emigrant or to a farmer at home shifting his quarters, is very great; and the whole subject is worthy of far more attention than it has received from practical men. Here, however, our limits forbid us to do more than simply to enumerate the more important of the geological formations of Great Britain and Ireland, and to state the agricultural soil that their surface affords. It will be understood that the enumeration is not complete, but only extends to the formations of greatest extent and consequence.

Among the latest or tertiary formations, as they are called, we may first mention that of the *London clay*. This extends over the greater part of Middlesex, the south-eastern half of Essex, and the southern half of Hampshire. The soil that it forms is naturally strong and very tenacious, adhering firmly to agricultural implements and to the feet; but, when drained and lightened by frequent admixtures with the abundant London manure, it becomes good meadow land, but as yet, as arable, it has been found difficult to work. This is probably partly owing to its imperfect drainage.

The *plastic clay* formation, as it has been named, surrounds the London clay, and occupies a large space in Hampshire,

* For example, one of the best of these dissertations on horticulture devotes eighty-five pages to the subject of forcing, and only fifty to the varieties of out-door culture of all the esculent vegetables.

RYDER'S PATENT FORGING MACHINE.

Fig. 3.

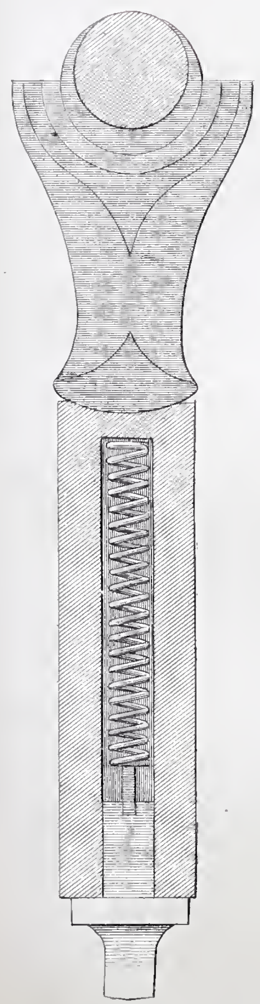


Fig. 1.

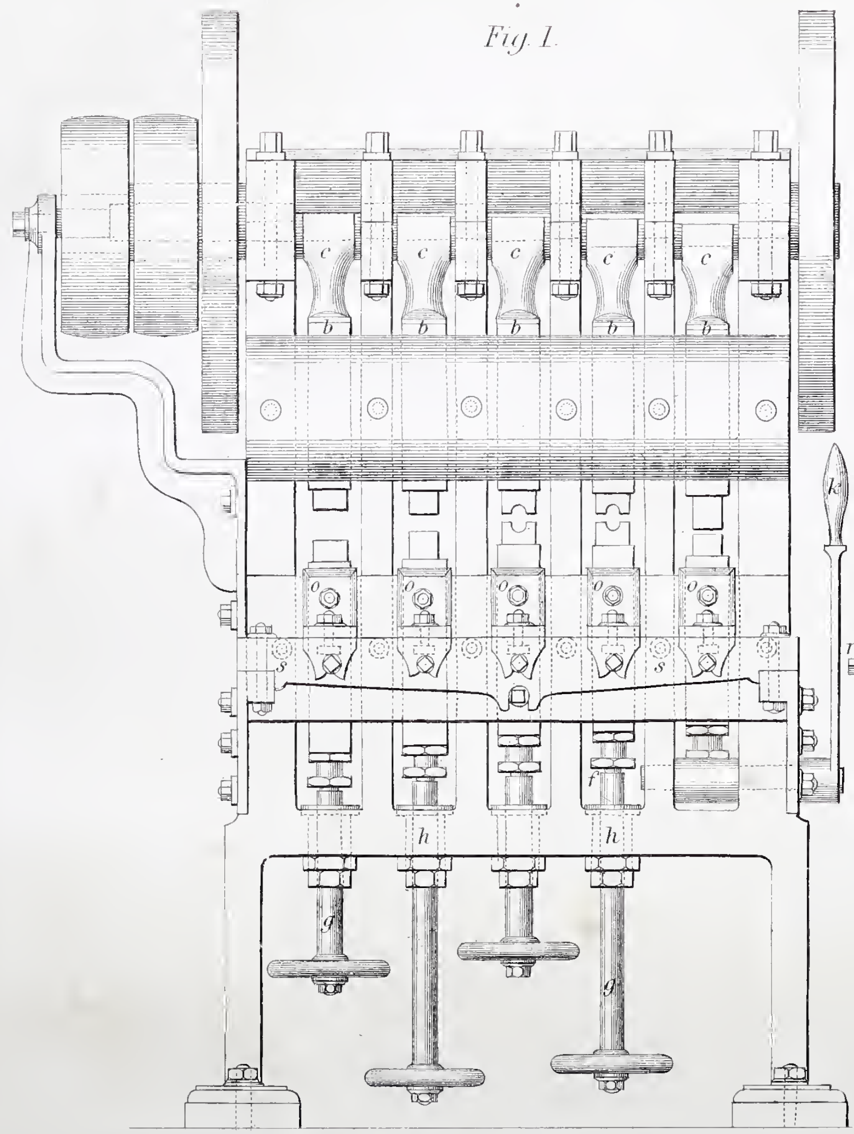


Fig. 2.

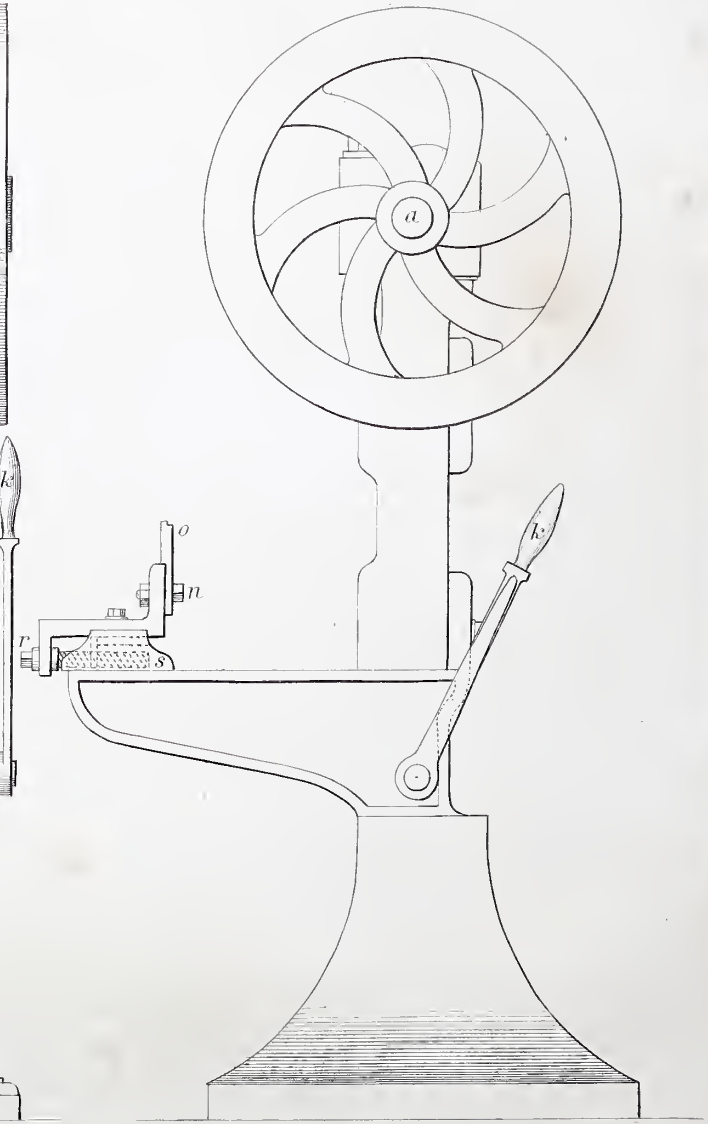
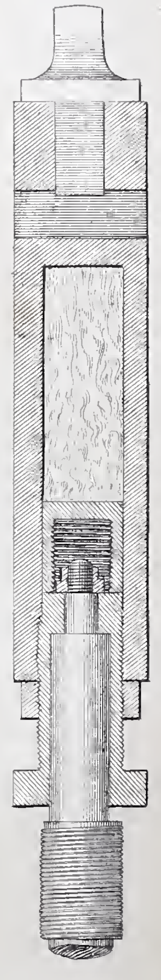


Fig. 4.



Dorset, Essex, Suffolk, Norfolk, Kent, and, but to a less extent, other counties. It consists of beds of sand and clay, and sometimes, as in Norfolk and Suffolk, the sand rests upon chalk. This is likewise the case in a great part of Hampshire and Berkshire. Naturally these tracts produce nothing but heather. But, by bringing up the lower bed of chalk, the soil becomes excellent arable land. However, with the exception of these places, the land lying over London clay and plastic clay is not naturally productive, and is not well managed.

Among the secondary formations we may first notice the chalk. This constitutes a great part of the south-east of the island. It runs in a broad band from the south-west of Dorsetshire to the north of Norfolk, and then turning north, passes through a part of Lincolnshire, and terminates in the coast of Yorkshire, at Flamborough Head. All the soil lying over this formation is particularly suited for herbage, and the high-lying parts of it have been famous for ages as sheep-walks. But, when ploughed, it forms excellent arable land. Still, there is always a strong tendency shown by those who farm it to keep great parts in permanent pasture. It is upon the chalk that lucerne and sainfoin flourish.

Another secondary formation is the oolitic. It is found in Yorkshire, whence it extends right down to Dorsetshire; and it occurs, but over a very small area, in portions of Sutherlandshire and Skye. The soil lying over oolitic formations varies a great deal in quality. A great part of it is very tenacious, and if not drained, as is too often the case, produces very inferior crops. The fens of Lincoln, Northampton, Huntingdon, Cambridge, and Norfolk, rest upon the oolite.

Although totally different formations, and having the carboniferous or coal between them, we may, in an agricultural point of view, regard the new red sandstone and the old red sandstone as one. The new red begins in the south of Devon; runs north-east into Somersetshire; extends up both banks of the Severn into the vale of Gloucester; then expanding, includes the counties of Warwick, Stafford, and part of Leicestershire. Here it parts into two; one branch forms Cheshire and part of Lancashire; and appears again in Cumberland, forming the north of it, and a portion of the south of Dumfriesshire; the other branch forms a part of Derbyshire, Nottinghamshire, and Yorkshire.

The old red sandstone forms part of Wales, Berwickshire, part of Haddingtonshire, and other districts in the south of Scotland; runs across Scotland from Stonehaven to the Clyde; appears again in Caithness; and forms the Shetland Islands.

These red sandstone formations are *the* agricultural soil, *par excellence*, of Great Britain. It is over them that the modern improved farming first began, and to them it is but too much confined even yet. Land lying over them requires, in order that its capabilities may be developed, to be drained.

The carboniferous or coal formation is present in districts of the lowlands of Scotland, the north of England, and parts of Wales. Soil formed by its disintegration is invariably of an inferior quality, and is what the farmers call "cold and deaf." In skilful hands, however, and where manure is liberally applied, good crops may be obtained over the coal.

There is a class of formations to which we may give the name of silurian or greywacke, which compose the greater part of Wales, Cornwall, and a tract of the south of Scotland, including the Lammermuir hills, and a great portion of Peebles, Selkirk, Dumfries, and Wigton shires. The soil that greywacke forms is invariably very bad, and is very little cultivated as arable land, being principally employed as sheep pasture. Being very tenacious, it is very bad unless drained. The other cause of its infertility is want of lime. Drainage, then, and the application of lime, are the proper plans to be adopted over greywacke, and, except where the elevation is too high, would probably effect a great change upon these now unproductive wastes.

The gneiss and mica slate formations include nearly the whole of Scotland north and west of the Grampians, and a great part of Mayo, Connaught, Galway, Donegal, and Londonderry, in Ireland. Generally speaking, these districts are very mountainous, and, moreover, the frequent rains which fall upon them wash down the soil. When this latter is the case, the thin sandy soil thus left behind is unproductive; but that which is washed down into the valleys is good enough. The kind of farming that is found to do best over gneiss is the breeding and raising of cattle.

Granite rocks occur in Cornwall and Devon, in Kirkcudbrightshire, and in many parts of Scotland north of the Grampians. These rocks vary a good deal in their composition, and, therefore, in the soil which they form. Being usually steep mountains, the soil is frequently washed down into the valleys. This soil is well suited for grass; and the main aim of farmers, in granitic countries, is to raise cattle.

Trap, or volcanic rocks, are scarcely known in England. In Scotland, they form the Cheviots, and extensive districts in Roxburgh, Haddington, Lanark, Ayr, Linlithgow, Stirling, Kinross, Fife, Perth, and Forfar. The soil they make is almost uniformly good, and the same mode of culture is followed in it as in the red sandstone districts.

FROMINGS' PATENT FORGE-HAMMER.

The patentee of this improved forge-hammer (enrolled April 16, 1852) is Mr. Thomas Henry Fromings, of the firm of Lomas, Fromings, & Co., of Sheffield. The improvements, as stated in the inventor's specification, consist in so constructing the machine, that it may be applied to all kinds of forging with much greater facility and economy than the power-driven hammers hitherto in use; and further, in rendering it better adapted for forging many smaller articles, which are now entirely forged by manual power applied directly to the shaft of the hammer.

Fig. 1.

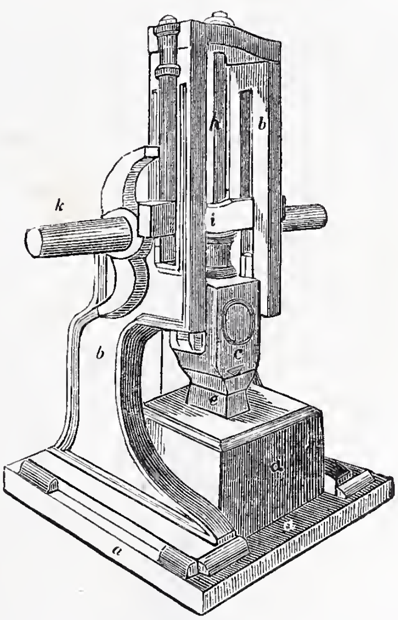
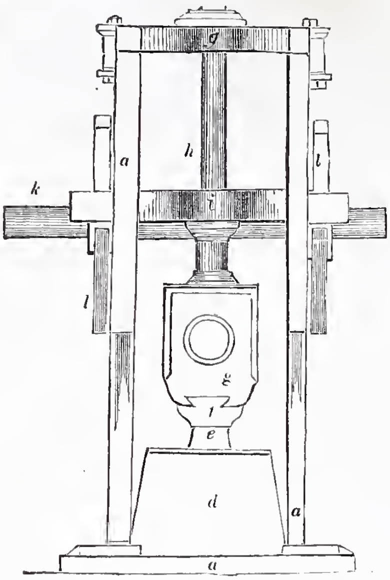


Fig. 1 is a perspective view of this machine; fig. 2, a front, and fig. 3, a side elevation. A A is a basement plate, mounted upon large ashler stones, under which oak beams are laid, the whole being fixed together by holding-down bolts; B, B, are standards, forming the framework, bolted at their lower ends to the base-plate, and at their upper ends to the cross-head or guiding-rail, C. D is the anvil-block, firmly fixed to a block of wood; E, the anvil, and F, the hammer, attached to the hammer-head, G. H is a vertical guide-rod, carrying the hammer-head, which is securely keyed to its lower end, and working at its upper end through a brass in the top-rail, C. The cross-head, I, is rigidly fixed to the guide-rod, H, and

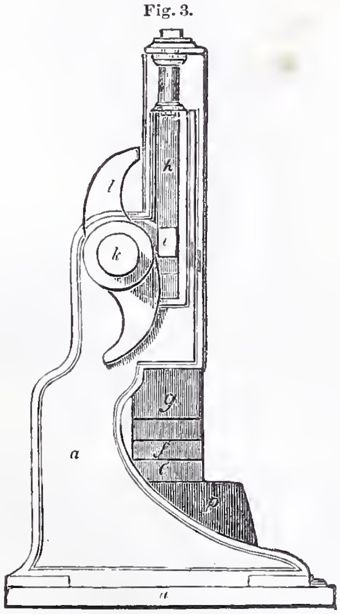
works freely up and down in slots in the side frames, through which its ends project a little on each side. K is the driving-shaft, which has its bearings in brasses mounted in the framework, B; and L, L, are cams revolving with this shaft, so as to strike in their revolutions the projecting ends of the cross-head, I, which is thereby raised, together with the hammer-head and hammer. The cams are represented in the engrav-

Fig. 2.



ings with two arms, but these may be increased to any number, or reduced to one, according to the speed at which it is desired to work the hammer, or the power at disposal for that purpose. When the hammer is to be driven very fast, the patentee attaches a helical spring to the guide-rail, C, which passes round the rod, H, and is fixed at its lower end to the

Fig. 3.

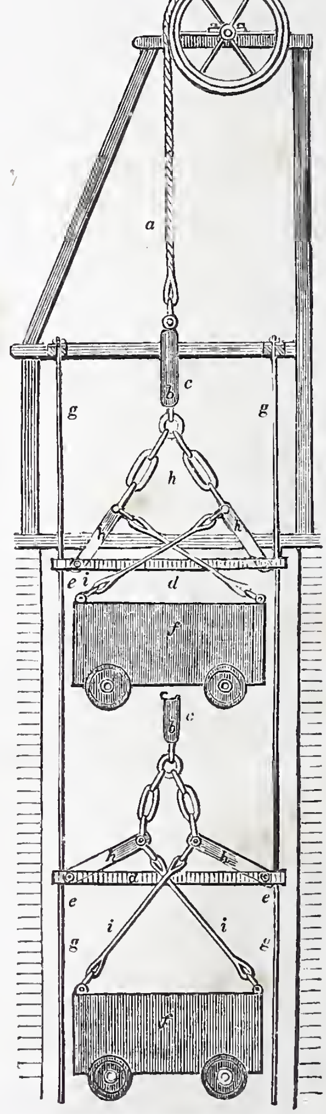


cross-head, I. This spring, when the hammer is raised and released from the cams, not only accelerates its descent, but increases the force of the blow. The power may be applied to the driving-shaft by any suitable contrivance, and may be derived from any prime mover, such as steam, water, or even manual labour.

This machine is described by the inventor as applicable to a lighter class of forging than the ordinary forge-hammers, driven by power, besides being more conveniently, and with less cost, applicable for heavy forging. He claims as his invention the general arrangement, combination, and adaptation of parts of which the machine consists, especially in so far as regards employment of cams attached to a revolving shaft, to actuate the cross-head affixed to the guide-rod of the hammer, and also of springs, whether of the helical or any other form, to accelerate the descent and increase the force of the hammer.

SMITH'S ELASTIC SAFETY CAGE FOR MINES.

Thanks to modern ingenuity, even the most timid may now descend to the bottom of a coal or ironstone pit without trepidation. The means are invented, though not yet generally applied, of making the subterranean excursion—if we may so call it—perfectly safe. This would be a small boon if it only regarded the safety of a few casual visitors; but when it is considered that a large portion of the industry of this country is doomed to work perpetually in subterranean fields, which furnish the most valuable sources of our wealth, it will be admitted that any invention which tends to diminish the danger of communication with these extensive reservoirs of natural treasure, ought to be favourably received, and, if possible, generally adopted. Fourdrinier's safety-cage, and others on a similar principle, have been long known; but we have reason to believe that they have seldom been brought into use. The costliness of such inventions, and the difficulty of effectually working them, are generally found to be insuperable bars to their introduction, except in a few rare cases. But neither of these objections seems to apply with much force to the elastic safety-cage, of which a cut is annexed, and which is the invention of Mr. Andrew Smith, a gentleman well-know in the scientific world as having taken out nearly forty patents for new inventions, among which we may mention



his patent mode of galvanising iron with zinc, his metallic bath for the generation of steam, and his machinery for the manufacture of wire-rope. Mr. Smith has taken no patent for the safety-cage, which forms the subject of this paper,

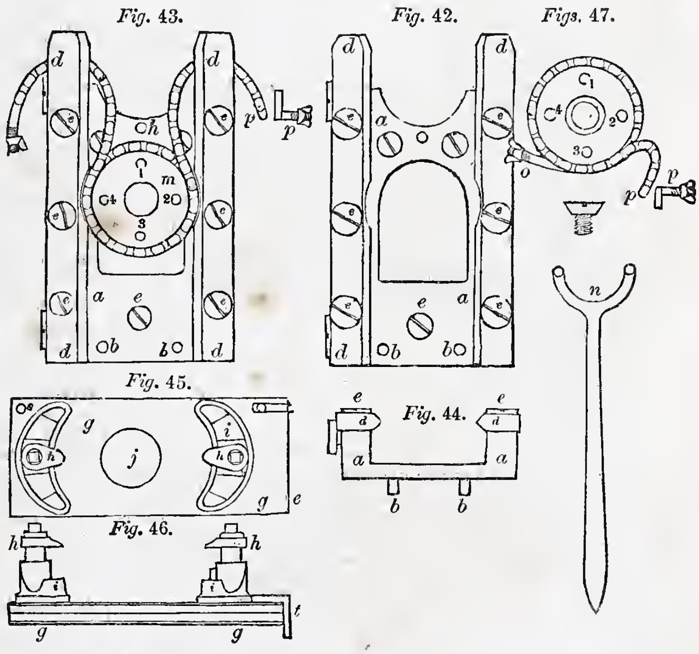
but has simply placed it before the public as a means of saving life, whieh may be adopted with greater security to the miners, and with less expenditure to the owners, than any other method yet known.

The accompanying diagram will fully explain the construction and principle of operation of this safety-machine. It exhibits the cage in two states:—first, before a fracture has taken plaee, and secondly, after a fraeture at the point *c*. *a* is the rope passing over the pulley; *b*, the elastic connecting tube; *c*, the point of supposed fracture; *f*, the cage; *g*, galvanized wire rope guide-rods; *d*, guiding bar; *e*, eccentric jamb-joint; *h*, connecting levers and chains; and *i*, cross conneeting-rods attaehed to the cage. The operation of the meehanism is as follows:—Supposing a fracture to take place at *c*, in the middle of the elastic connecting-tube (which obviates the danger arising from sudden jerks), the cage, *f*, by its instant descent, pulls inward the levers, *h h*, and these, by turning at the joints, *e*, are thus fcreed outward against the guide-rods, and aeting as a wedge, immediately arrest the farther descent. The detached cage in the diagram is shewn in this state, with the levers, *h h*, drawn down at one end, and thus brought to bear at *e*, against the guide-rods, *g*.

This machine might be fitted up at comparatively little cost, and we think that with ordinary care it would be found to afford a complete security in case of fracture. By substituting wire-ropes for the heavy wooden guide-rods adopted in other methods, it promises economy in the application. Unfortunately, it is not only between the mouth and the bottom of the pit, that danger from carelessness or other causes exists. It sometimes happens that the party who is in eharge of the engine forgets to arrest the upward progress of the cage after it has reached the mouth of the pit, and in that case, the load, whether of human beings or minerals, is dragged up into the air, sometimes a distanee of thirty or forty feet, and brought into contact with the pulley, or otherwise thrown out of the cage. Fatal results from this eause have been more frequent than even from the snapping of the rope, or the jolting of the cage, from mismanagement, against the sides of the shaft. We have seen a safety-cage construeted on such a principle, that by a very simple eontrivance, it became detaehed from the rope, if suffered, by aceident or inattention, to rise within a short distance of the pulley, and the guides being carried up all the way, it stood, in that case, suspended in mid-air, supported by the eatehes on each side. It would be well if something of this kind were incorporated with Mr. Smith's plan, wherever it may happen to be adopted. The constant exercise of human vigilance and caution is less to be depended on than even imperfect machinery. Carelessness and inattention on the part of workmen produce universally more accidents—if, in that case they may be called aecidents—than all other causes combined. This is seen every day; and hence the importance of trusting as little to human vigilanee as possible, where human life is risked. The perfection of a machine is to be self-acting; and in this respeet we believe, that with the small addition whieh we have suggested, Mr. Smith's safety-cage would be almost, if not quite perfect.

DESCRIPTION OF HOLTZAPFFEL & CO.'S LATHE CHUCKS.

(*Continued from page* 631, *Vol. I.*)



Straight Line Chuck.—This ehuek is composed of a brass frame *a*, which is firmly fixed to the front of the lathe, by means of the three steady pins *b* and the three screws *c*: *d d* are two steel bars with double bevelled edges screwed to the chuck by the six screws *e e e e e e*; the holes in one of these bars through which the three screws *e* pass are of an oval form, to allow room for regulating the distance by means of the side screws *f f*, in case the slide gets any shake by wear, or other circumstance. The other bar *d* has not this contrivanee, nor does it require it.

g, seen in figs. 45 and 46, is a slide which fits into the brass frame *a*, and works freely between the steel plates. *h h* are two screws and clamps, which are fitted into the two projecting pieces *i i*; *j* is a socket turned to fit the nozzle of the screw of the eccentric chuek; *m* is a brass drum which screws on the lathe—an operation which is most readily effected by the key *n* of fig. 47; *z* is a screw for the purpose of fixing the drum more seeurely from coming off the screw which screws in the centre of the mandrel, and bears against the bevelled edge of the hole in the drum; *o* is a steel chain fitted to the brass drum, which chain has a screw, nut, and washer, for fixing it; *p* is also a steel chain, which has an elbow screw and nut.

The Method of Fixing the Straight Line Chuck on the Lathe is this:—1. Fix the brass frame *a* on the front of the lathe-frame by means of the three screws *c*, taking care that the steady pins be in their places.

2. Screw the drum *m* tightly on to the end of the mandrel with the key *n*, and put the screw in its place; that is, in the hollow screw on the end of the mandrel.

3. Place the chain *o*, so that it coils round the drum in the direetion of the figures 1, 2, 3, 4, and that its serew-nut and washer hang over the left-hand corner.

4. Plaee the chain *p* so that it coils round the drum in the contrary direction.

5. Place the slide, figs. 45 and 46, between the steel plates, *d d*, from the top—only entering it.

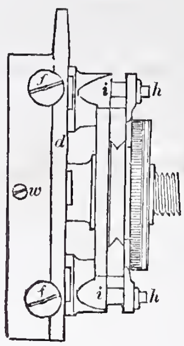
6. Place the elbow-screw of the chain *p* upright in the holes *s* in the slider, and fix it there by the nut belonging to it.

7. Fix the screw of the chain *o* in the hole of the steel elbow-bracket *t*, and fix it there by the nut and washer whieh belong to it.

The side screw *w* is for the purpose of preventing the drum making a greater revolution than to which the chuck is adapted; it must be screwed close up to its place when the chuck is put together for use. The end of it works in a groove at the back of the drum *m*, and prevents it making any unnecessary or injurious motion by coming in contact with a small steel arc fixed to the drum itself, at the same time allowing it as much motion as the chuck is calculated to require.

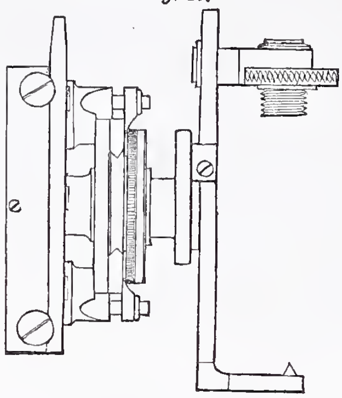
The method of fixing the Eccentric Chuck on the straight line Chuck, will be understood by reference to fig. 48. It must be so placed that the nozzle of the eccentric chuck, which otherwise goes on to the lathe, enters the socket *j* of the straight line chuck, and that the steady pin *x* enters a little hole in the back of the eccentric chuck, in which situation it must be clamped down by the two clamps and screws *h h*, in which case, if the nature of the straight line chuck were to revolve, the eccentric chuck would run true upon it.

Fig. 48.



The method of fixing the Pillar-fluting Chuck upon the Straight Line Chuck is this :—Having fixed on the eccentric chuck, as last described, the pillar-fluting chuck must be screwed on the same. This chuck is mostly required in a vertical position, which can be regulated by the toothed wheel of the eccentric chuck, and finally, by the two side regulating screws of the pillar-fluting chuck.

Fig. 49.



By means of this compound chuck, columns, squares, or any other polygonal pieces, may be variously ornamented.

Universal Chuck with Two Slides.—This chuck consists of

Fig. 50.

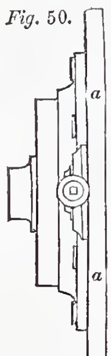
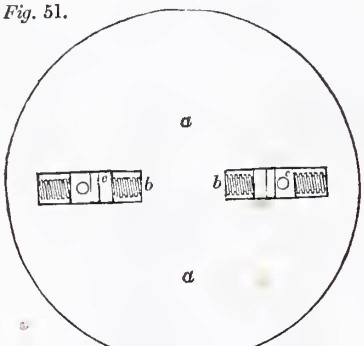


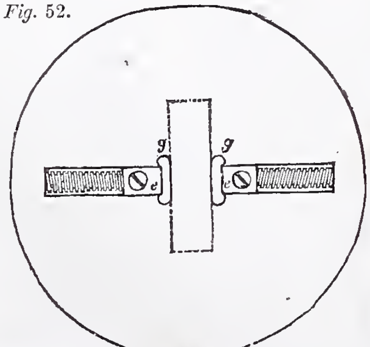
Fig. 51.



a steel plate *a*, which has two diametrical grooves in it; *b* is a double steel screw; that is, to say one-half of it is of a right-handed, and the other of a left-handed thread. *c c* are two carriages fitted into the grooves, and which are moved by the screw *b*, which moves them equally, but in different directions.

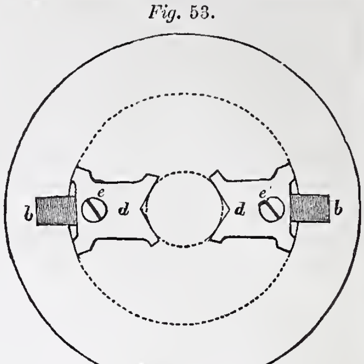
g g are two clamps, whose outside edges are circular, for holding small diameters from the inside, their inside edges being straight and at right angles from the groove. They are fit for fixing square or plain work.

Fig. 52.



If the work be required on one side it can be packed up with wood, &c., till that part be in the centre which is required.

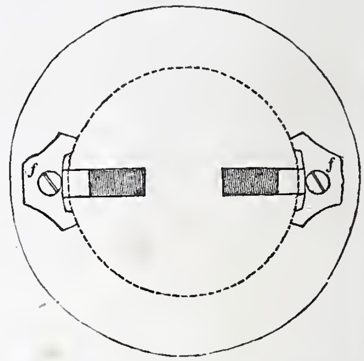
Fig. 53.



d d in fig. 53 are two holders, which are fixed to the carriages by two screws *e e* belonging to them. The inside edges of those nearest the centre are of an inverted angular form, and are for holding small diameters, the outside edges of which holders, being circular, are for holding large diameters from the inside.

f f in fig, 54 are two clamps, whose inside edges are circular, for holding large diameters from the outside.

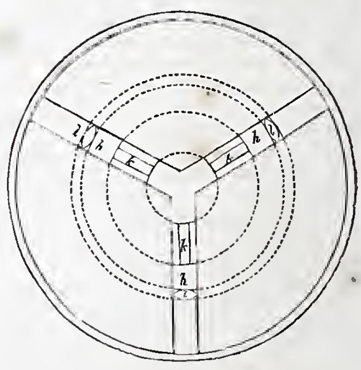
Fig. 54.



The chuck may also be provided with clamps, having angular edges inside for the same purpose, and which will allow of their application to a greater number of sizes than the circular edges will suit.

The angular edges of the holder in fig. 53, may, in like manner, be replaced by circular edges, should these be thought preferable for certain kinds of work.

Fig. 55.



Universal Chuck with Three Slides.—This is provided with machinery for moving the three carriages *h h h* equally and all at the same time, either to or from the centre, which is effected by turning the screw *i*. *k k k* are three steel clamps in the form of levers, which are fixed in the carriage *h*. When the outside ends of these are elevated they will hold small rings, &c., from the inside; when the inside ends are elevated they will hold small work from the outside. *l l l* are for holding work from the inside or outside. *m m m*, seen in fig. 57, are three clamps which are fitted on the projecting pieces *l l l*, and are secured by the screws *o o o* ; the ends of those nearest the centre serve for small diameters, the middle part for holding work about five inches from the outside, the extremities for holding large work from the inside or outside, as shown by dotted lines. This chuck is exceedingly useful, as it

Fig. 56.

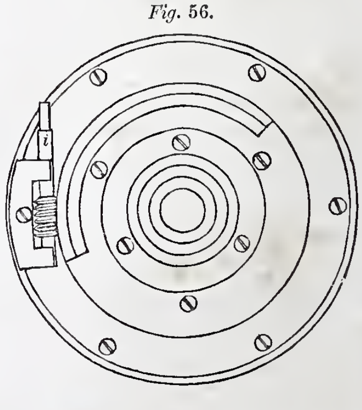
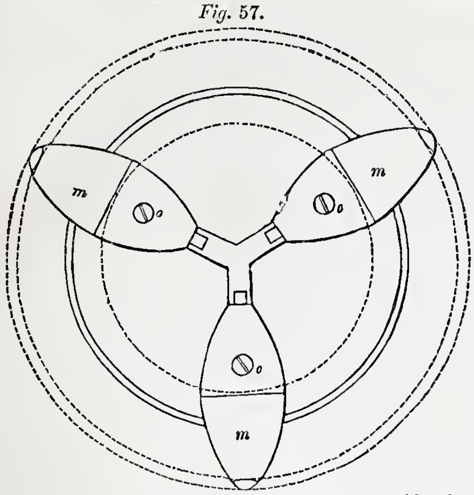


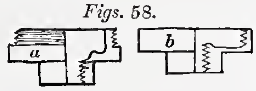
Fig. 57.



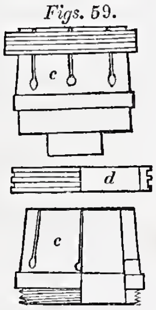
holds circular work either from the inside or outside, from the smallest size to ten inches diameter; but, in which case, the lathe heads must be raised to allow the chuck room to revolve.

Screw Chucks.—These are made in pairs as figs. 58; the one *a* having an outside screw, and the other *b*, an inside screw, which two fit together. Chucks of this description are very useful for ornamental purposes, as the work can be fixed upon them very near to the lathe—a great advantage, in so far as the work is not so liable to spring. They are also used in the double spring chucks of the following description for in-and-outside work.

Figs. 58.



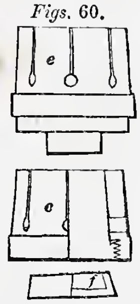
Figs. 59.



c of figs. 59, represents a ring of boxwood, with a screw cut in it similar to the screw in the metal (brass) chuck *b* of figs. 58, to which it fits. In this ring *c* are cut several slits with a saw in the direction of so many radii: *d* is a ring of brass for the purpose of compressing the ring *c*. The vacant spaces formed by the saw-slits allow of this compression, that is, allow the wood to be pressed together upon the work inside when the ring *d* is put on.

e in figs. 60, represents also a ring of wood similar to *c*; this fits on the metal chuck *a* of figs. 58. This ring *e* is cut in the same manner as the ring *c*, but acts directly the reverse, the inside of the ring being a portion of a cone whose angle is two or three degrees. *f* is a conical brass block which is introduced within the ring; and when pressed upwards from behind, it opens the wooden ring *e*, and so fixes the work upon the outside of the same.

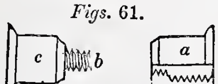
Figs. 60.



These we may call *spring chucks;* they act like a vice, the one inwards, and the other outwards, and are sufficient and convenient for holding work either for turning or polishing. They have also an advantage in allowing the work to be fixed without any percussive force being used, which in many cases is not admissible.

Figs 61, represent a pair of screw chucks for small work. The one is fitted with an inside and the other with an outside screw. The inside one *a* is tapped in the brass, and the outside one *b* is made on a steel pin which is set into the brass chuck *c*. These two chucks fit together, and are very useful for small work which is intended to screw together, as they save the trouble of turning chucks of wood, and are very frequently the readiest mode of fixing.

Figs. 61.



Figs. 62, a pair of screw taps. These are made in sets of six different sizes, and are intended for cutting screws in any work which may require fixing upon the external screw chuck *b* last described. The tapered one *a* is first used, and afterwards the plug or cylindrical tap *b*, is inserted to equalize the hole. The work is then ready to be screwed upon the chuck.

Figs. 62.

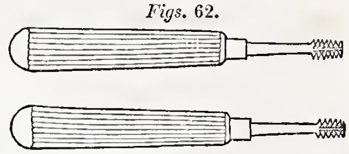


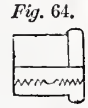
Fig. 63, represents a steel chuck with a steel worm. It is in the form of a flanch and has a steel conical screw in the centre. This chuck is very useful for fixing work on account of its simplicity, as it only requires a hole to be made in the work with a gimlet or any other instrument, to allow of its being screwed on the steel worm till it bears equally on the face of the chuck. It is also very convenient for shaped work, but is most adapted to plank wood.

Fig. 63.

When it is required to turn a wheel, &c., in whose centre there must be no hole whatever, or in which there may be a hole already too large, a piece of wood may be glued on for the screw to fix in.

Fig. 64 represents a screw chuck with an inside screw. This form of chuck screws on the lathe, and when it is in this position, it represents an inside screw, and affords all the convenience of a mandrel, with inside screw.

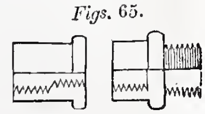
Fig. 64.



Small wood chucks with outside screws are also used in this chuck for small work.

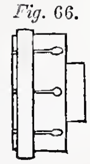
Figs. 65, represent a pair of double screw chucks with in-and-outside screws. They are intended for the following purpose: Suppose the mandrel to have an external screw, by having a chuck to screw upon it with an internal screw, it would possess all the advantages of a mandrel with an internal screw, and would serve at the same time for screwing on the smaller kind of chucks, such as the arbor chuck, of steel and brass, the wire chuck with steel rings, &c., which are not unfrequently fixed in this way. On the contrary, if the mandrel had an inside screw by having a screw chuck with outside screw, the lathe would be much more complete, the outside screw being mostly preferable for fixing common wood chucks.

Figs. 65.



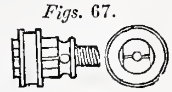
Spring Chucks.—Two forms of these have already been described in figs. 59 and 60. That represented in the annexed fig. 66, is supposed to be formed of thin metallic (brass) tube, rather conical outside, and smallest in front. The tube is divided by saw-slits, into four or more sections, and a steel ring is intended to be driven on the outside of it with a mallet, to contract the diameter and cause the periphery of the tubular part to close securely upon any work that may be placed within it.

Fig. 66.



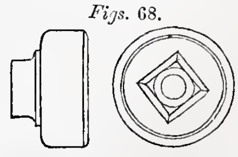
Wire Chucks with Steel Rings.—These screw in the hole inside the mandrel on a small double screw chuck, such as figs. 65. They have a hole throughout to receive a wire of the same size, and are sawn down the middle, so as to spring inwards and fix the wire when the steel ring is driven on.

Figs. 67.



Square Hole Chucks.—These are for the purpose of turning small pieces of metal, ivory, or any other hard substances. One end of the work must be made square to fit the chuck, and the other must be supported by the front centre of the lathe. It is also convenient that the side of the work corresponds with the marked side of the chuck, so that it can be taken out and replaced without any trouble whatever, and the mark will serve as a guide to place it by in the same position as before in the chuck.

Figs. 68.



These chucks are also fitted with holes of brass from $\frac{1}{2}$ inch to 2 inches square, for the purpose of turning wood, as for handles, &c.

CHEMISTRY OF ORGANIC NATURE.

CHAPTER I.

THE VEGETABLE KINGDOM.

CONSTITUENT ELEMENTS OF PLANTS—WHENCE AND HOW DERIVED—CONDITIONS OF GROWTH—ASSIMILATION.

NOTWITHSTANDING the perplexing diversity of aspect under which the productions of the vegetable kingdom present themselves to our observation, in the hands of the chemist they evince a simplicity and similarity of constitution which are truly remarkable. Not only are the most opposite types of vegetable life found to consist of the same ultimate elements; but these elements—which are, moreover, few in number—not unfrequently go to the formation of parts the most unlike, and products the most distinct in their physical characters. This position is aptly exemplified in the tough and dry fibre of wood, which certainly bears little resemblance to such substances as starch, sugar, and gum; experiment, however, proves it to be identical with them in constitution, and to consist like them of carbon and the elements of water. These last, indeed, constitute almost the entire mass of vegetable matter; and in the relations named—the oxygen and hydrogen being present in such proportions as to produce water by combination—they form the principal bulk of every vegetable structure. When the oxygen element predominates—when it is greater than would be required to produce water by union with the hydrogen present—another class of vegetable compounds results. To this class the numerous vegetable acids, with few exceptions, belong. The contrary of this condition, the hydrogen being in excess, gives rise to a third class of compounds comprehending the volatile and fixed oils, wax, and resins of plants.

But although we recognise in carbon, oxygen, and hydrogen, the principal elements which go to the formation of vegetable structures, there are yet other elements which seem to be equally essential to the development of vegetable life. These are nitrogen and certain earthy bases which, on a former occasion, we showed to be metallic oxides. These last exist in every plant, and may be detected in its ashes after incineration. Nitrogen also—although, when estimated by its proportional weight, it forms only a small portion of plants—is never entirely absent from any part of a vegetable structure. It may not, indeed, enter absolutely into the composition of a particular part; yet it is ever present in the fluids which pervade it, and in some grains and flowers it forms a most important element.

The methods of analysis by which these facts have been established are intricate; but a very simple experiment is all that is necessary to supply us with that amount of information which our present purpose requires. Suppose we put a piece of green wood into an iron retort, and place this in a clear fire with the beak projecting beyond the fire, as the wood becomes heated, the water, which is the chief ingredient of its juices, distils over and drops from the beak of the retort. In proportion as the water distils, from being insipid it becomes sour. Shortly after a gas begins to issue from the retort, and may be collected by tying a moist bladder round the mouth of it. If, when gas ceases to issue, the contents of the retort be examined, the piece of wood will be found altered into a black, dry, cinerous mass, retaining, however, its texture, although much reduced in size. It is, in short, converted into charcoal (in chemical language *carbon*), and if its weight be added to that of the gas, the mere water, and the sour water, the result will be the original weight of the wood without loss; and hence we conclude that these are all the ingredients which composed the wood.

To carry the analysis a step further, let the charcoal be burned in the open air; it will burn almost entirely away, leaving only a little white ash of no considerable weight. This residuum, if properly examined, will be found to consist chiefly of potash and lime, with probably an admixture of soda and magnesia. If the nature of the gas given off be next inquired into, it will be found to consist principally of that compound of carbon and hydrogen which is now so extensively manufactured from coal, for the purpose of artificial illumination. It will be found also to contain free hydrogen, and two gaseous compounds of carbon and oxygen; the first of these burns in the atmosphere with a pale blue flame, thereby passing into carbonic acid, which is the name of the second compound of carbon with oxygen present, and which extinguishes any burning body immersed in it. The sour liquid, obtained by the distillation, will, upon examination, be found to have the power of turning vegetable blues to red, and of forming certain definite compounds with alkalies; it is therefore an acid, and from its being once believed to be different from all others known, it obtained the name of *pyroligneous acid*, to indicate its being produced from wood by fire. In its crude state it has the taste and smell of tar, which is a vegetable product obtained by exposing wood to a strong but smothered heat, such as that to which the wood was submitted in the retort; but when the tar is separated from the acid, and a process has been contrived for effecting this object, the true nature of the acid becomes immediately known: its smell being no longer disguised, it is at once recognised to be vinegar—an acid which in this country is made on the large scale by the very process indicated.

We thus perceive that the exposure of wood to a high temperature affords a number of compounds. There are two combinations of carbon and oxygen, at least two of carbon and hydrogen (carburetted hydrogen gas and tar), and one (vinegar) consisting of carbon in combination with both hydrogen and oxygen. We see that pure hydrogen is also extricated; and if we examine the acid carefully, we shall observe that a little nitrogen likewise existed in the wood, and came off during the distillation in union with hydrogen, forming ammonia, which the acid retained. These, with the charcoal and the metallic oxides contained in it, are the results of the process. As a general summary, we may recapitulate, that from a piece of green wood we obtain hydrogen, carburetted hydrogen, carbonic oxide and carbonic acid, vinegar or acetic acid, as it is called in the language of chemistry, holding tar, ammonia, and charcoal. By multiplied and accurately conducted experiments of this kind on other vegetable structures, we learn that all of them, however dissimilar in their external characters, and however dissimilar they may be reckoned by the botanist, when made to undergo the ordeal of heat in confined vessels, resolve themselves like wood into the four elements—carbon, oxygen, hydrogen, and nitrogen, with slight and inconstant traces of earthy matter. These again, by combining among themselves, produce the proximate vegetable compounds, of which all vegetable organisms are composed.

We have selected wood as an appropriate example for elucidating the constitution of vegetable matter; because it is a fair representation of all other vegetable bodies when submitted to *destructive distillation*—as the exposure of decomposable matter in close vessels, at a high temperature, is commonly called. But it is only when submitted to this process of decomposition that wood can be justly regarded as the representative of other vegetable bodies, and when we look at the ultimate products of the distillation. The carbon, oxygen, hydrogen, and nitrogen, we denominate the ultimate elements of vegetables; because the decomposition has proceeded to the last stage that is attainable in their analysis. But, besides these and their immediate combinations, formed during the distilling process, there are other combinations which naturally exist in the vegetable structure, and which offer themselves to our observation without being subjected to any complicated process. These combinations being the nearest to the natural constitution, and the more immediate objects of sense, when we examine any vegetable organization, we denominate them the proximate principles of vegetables. It is not necessary in this place to describe them

individually. They are numerous; but the three classes of them already indicated at the beginning of this article exemplify them sufficiently well for our present purpose.

From the facts thus far detailed, it follows that a plant, in order that it may live and grow, requires the presence of carbon and nitrogen, and also of water and its elements (oxygen and hydrogen), and likewise of a soil to furnish the inorganic elements, which seem, from their being ever present in vegetable structures, to be essential to their development. As regards the last-named elements, we experience little difficulty in accounting for their assimilation by growing organisms: the soil and the atmosphere contain them in abundance. But when we observe the large proportion of charcoal which remains when a piece of wood is subjected to the action of heat, under circumstances which prevent combustion, we are naturally led to inquire whence the enormous supply of carbon, which is continually becoming fixed by the growth of plants over the surface of the globe. It has indeed been averred that, like potash and the other inorganic elements found in vegetables, it may be derived from the soil upon which the plants grow; and it is true that no soil is entirely devoid of it. But the carbon existing in soil is acknowledged to have been furnished to it by the decay of vegetable matter upon its surface. This leads us to inquire whence the first vegetables which grew upon it derived their carbon? They did not create it; and if not found in the soil, our next and natural conclusion is, that we must look to the atmosphere as the grand reservoir of this pabulum of vegetable life. But carbon cannot and does not exist in an uncombined state in the atmosphere: it there exists in union with oxygen, forming the gas described on a former occasion as carbonic acid. This is now recognised as the real source of vegetable carbon, the true food of plants.

But this fact, which we merely announce, without waiting to prove its correctness, involves, in the words of Professor Liebig, the consideration of two most remarkable natural phenomena, which, by their reciprocal and uninterrupted influence, maintain the existence of both kingdoms of organic nature. In describing the constitution of the atmosphere, we stated the volume of oxygen in it to constitute a fifth of the whole mass: more nearly, it constitutes twenty-one hundredths of it. But this quantity, although it appears very great when stated in numbers, is not inexhaustible; and the process of abstraction is incessantly going on. Every animal that breathes, and every fire that is kindled, respectively breathe and burn by virtue of the oxygen which they consume. A man alone, as a condition of living, must consume somewhere about ten thousand cubic feet of oxygen in a year. A thousand millions of men must accordingly consume ten billions of cubic feet in that period of time.* But when we consider that the quantity of oxygen in the atmosphere does not diminish in the course of ages—that the air, for example, of the present day does not contain less oxygen than that found in jars which had been buried for 1800 years among the ruins of Pompeii—we cannot avoid inquiring how the equilibrium is maintained? Does there exist any source whence the oxygen abstracted is replaced? The answer to this question depends upon another, which is this—What becomes of the carbonic acid produced during the respiration of animals and the process of combustion? It is known that a cubic foot of oxygen gas, by uniting with carbon so as to form carbonic acid, does not change its volume; consequently the billions of cubic feet of oxygen abstracted from the atmosphere, produce, by respiration and combustion, the same number of cubic feet of carbonic acid to supply the place of the combined gas.

From numerous carefully conducted experiments, it appears that the quantity of carbonic acid in the atmosphere may be regarded as nearly equal to $\frac{1}{1000}$th part of its weight; and although the quantity varies with the seasons, the yearly average remains constant. We have no reason to believe, observes Professor Liebig, that this proportion was less in past ages. On the contrary, we find that all earlier observers describe its volume as from one-half to ten times greater than that which it has at the present time: we may hence, at most, conclude that it has not diminished. It is therefore evident that the quantities of carbonic acid and oxygen in the atmosphere, which remain unchanged by lapse of time, must stand in some fixed relation to one another; a cause must exist which prevents the increase of carbonic acid by removing that which is constantly forming; and there must be some process going on to replace the oxygen which is removed from the air by the process of combustion and putrefaction as well as by the respiration of animals.—Both of these causes are united in the process of vegetable life.

The facts already detailed are sufficient to lead us to inquire whether plants derive their carbon exclusively from the atmosphere; and, seeing that carbon exists in the atmosphere only in the form of carbonic acid, whether they have the power of decomposing that gas, appropriating its carbon to their own use, and setting the oxygen free to be returned to the atmosphere? Both of these inquiries have been answered affirmatively in the most certain and direct manner. From Priestley downwards it has been known that the leaves and other green parts of plants absorb carbonic acids and emit an equal volume of oxygen. They possess this property quite independently of the plant; for if, after being separated from the stem, they are placed in water containing carbonic acid, and exposed in that condition to the sun's light, the carbonic acid is after a time found to have disappeared entirely from the water. If the experiment be conducted under a glass receiver filled with water, the oxygen emitted from the plant may be collected and examined. If the experiment be repeated with water which either contains no carbonic acid, or which contains an alkali that protects it from assimilation, no oxygen gas is emitted.

It has also been shown that plants increase in weight during the decomposition of carbonic acid and separation of oxygen; and further, that this increase in weight is greater than the quantity of carbon assimilated—a fact which confirms the view that the elements of water are assimilated at the same time.

From these facts, we perceive that the life of plants is connected with that of animals in the most simple and admirable manner. The former not only afford the means of nutrition for the growth and continuance of animal existence, but they likewise furnish that which is essential for the support of the important vital process of respiration; for, besides separating all noxious matters from the atmosphere, the vegetable forms which cover the earth's surface are an inexhaustible source of pure oxygen, which supplies the loss the air is constantly sustaining. Animals on the other hand expire carbon, which plants inspire; and thus the composition of the atmosphere—the medium in which both exist—is maintained constantly unchanged.

It may be asked, says Liebig, is the quantity of carbonic acid in the atmosphere, which scarcely amounts to a tenth per cent., sufficient for the wants of the whole vegetation on the surface of the earth?—is it possible that the carbon of

* If the atmosphere possessed, in its whole extent, the same density as it does on the surface of the sea, it would have a height of 24,555 Parisian feet; but it contains the vapour of water, so that we may assume its height to be one geographical mile = 22,843 Parisian feet (that is, 24,344½ English feet, or 4¾ English miles, nearly). Now the radius of the earth is equal to 860 geographical miles; hence the

Volume of the atmosphere = 9,307,500 cubic miles = cube of 210·4 miles.
Volume of oxygen . . = 1,954,578 cubic miles = cube of 125· miles.
Volume of carbonic acid = 3862·7 cubic miles = cube of 15·7 miles.

The maximum of the carbonic acid contained in the atmosphere has not here been adopted, but the mean, which is equal to 0·000415.

A man daily consumes 45,000 cubic inches (Parisian).
A man yearly consumes 9505·2 cubic feet.
1,000 million of men yearly consume 9,505,200,000,000 cubic feet.
1 cubic mile is equal to 11,919,500,000,000 cubic feet.

Hence a thousand million of men yearly consume 0·79745 cubic miles of oxygen. But the air is rendered incapable of supporting the process of respiration, when the quantity of its oxygen is decreased 12 per cent.; so that a thousand million of men would make the air unfit for respiration in a million years. The consumption of oxygen by animals, and by the process of combustion, is not introduced into the calculation.—*Liebig's Organic Chemistry.*

plants has its origin from the air alone? This question is easily answered by reference to calculations, from which we learn that the atmosphere contains upwards of 3300 billions of avoirdupois pounds of carbon—a quantity which amounts to more than the weight of all the plants and all the strata of mineral and brown coal which exist npon the earth. This carbon is therefore more than adequate to all the purposes for which it is required.

It must also be observed, that not only do the leaves of plants absorb carbon from the atmosphere, but the roots and other parts of them which possess the same power, absorb constantly water and carbonic acid. This power is independent of solar light. During the day when the plants are in the shade, and during the night, carbonic acid is accumulated in all parts of their structure; and the assimilation of carbon and the exhalation of oxygen, commence at the instant that the sun's rays strike them. As soon as a young plant breaks through the surface of the ground, it hegins to acquire colour downwards, and the formation of woody tissue commences at the same time.

The proper, constant, inexhaustible sources of oxygen gas are the tropics and warm climates, where a sky, seldom clouded, permits the glowing rays of the sun to shine upon an immeasurably luxuriant vegetation. The temperate and cold zones, where artificial warmth must replace the deficient heat of the sun, produce on the contrary carbonic acid in superabundance, to be expended in the nutrition of tropical plants. The same stream of air which moves by the revolution of the earth, from the equator to the poles, brings to us, in its passage from the equator, the oxygen generated there, and carries away the carbonic acid formed during our winter. Such is the admirable provision of Nature: not only does vegetation improve the air by the removal of a gas, noxious to animal life, and by renewal of the gas necessary for respiration; but the horizontal currents of the atmosphere bringing with them as much as they carry away, insure a constant equilibrium of condition suited to the maintenance of both forms of living organization.

It has already been mentioned, that carbon and the elements of water form the principal constituents of vegetables: the quantity of the substances present which do not possess this composition are in very small proportion. It is not presumed that science has yet enabled us to pronounce with certainty on the manner in which these elements are assimilated; but, it is not difficult to suppose, that, under the influence of the solar light, plants may actually decompose water, and assimilate its hydrogen along with the carbonic acid. This is the position assumed by Professor Liebig in his admirable digest of organic chemistry; and, in order to show its tenableness, he goes at length into the arithmetical conditions which the problem involves. It is, however, unnecessary to go further into the calculation than to state, that if the mode of assimilation, as stated, be correct, 8 parts of hydrogen must unite with 100 parts of carbonic acid in order to form woody fibre, and that the $72\frac{1}{3}$ parts by weight of oxygen which was in combination with the hydrogen of the water, and which exactly corresponds in quantity with the oxygen contained in the carbonic acid absorbed, must be separated in a gaseous form, and returned to the atmosphere.

In cases where the vegetable structure contains more hydrogen than would be necessary to combine with the oxygen present in order to form water, we may fairly presume that water is decomposed to furnish the excess of that element; and, consequently, an equivalent of oxygen must be given back to the atmosphere for every equivalent of hydrogen appropriated by a plant to the production of those parts of its substance in which the hydrogen predominates. These are the green principle of the leaves, oils, wax, resins, and the like.

We are thus warranted in concluding that the process of assimilation in growing organisms consists, in its most simple form, in the extraction of hydrogen from water, and carbon from carbonic acid; in consequence of which either all the oxygen of the water and carbonic acid is separated, as in the formation of caoutchouc and the volatile oils which contain no oxygen, and other similar substances, or only a part of it is exhaled. Where acids are largely produced there is a deficiency of hydrogen, and, consequently, their formation is accompanied with the smallest separation of oxygen. Thus in cold summers, from absence of sunshine and the influence of heat, fruits remain acid; and, in our northern regions, most of our fruits predominate in acid properties, whereas within the tropics the most numerous trees are those which produce oils, caoutchouc, and substances of a like nature, which contain very little oxygen.

As nearly four-fifths of atmospheric air consists of nitrogen, we might suppose that the small quantities of that element contained in plants might be taken in directly from the general medium in which they live; but, as is well remarked by Liebig, we have not the slightest reason for believing that the nitrogen of the atmosphere takes a part in the process of assimilation of either plants or animals. All its known chemical properties are opposed to such a hypothesis. Of such a nature is it, that, if we except oxygen, it cannot be made to enter directly into combination, even by employment of the most powerful chemical means. Now, many plants, we know, emit nitrogen, and as they cannot absorb it directly from the atmosphere, it must enter them by the roots. As a direct experiment, it is found that plants grow perfectly well in powder of pure charcoal, if supplied at the same time with rain-water, but they will not grow if supplied with distilled water. Now, rain-water can contain nitrogen only in two forms, either as dissolved atmospheric air, or as ammonia, (a compound of nitrogen and hydrogen.) But we have said that the nitrogen of the air cannot be available in the process of assimilation, and may therefore fairly assume, that they are furnished with the nitrogen which they absorb by the ammonia. To strengthen this position, it has been further found that the formation in plants of substances containing nitrogen, such as gluten, takes place in proportion to the quantity of this element which is conveyed to their roots in the state of ammonia, derived from the putrefaction of animal matter.

But, when it is admitted that plants may derive a portion of nitrogen from ammonia, furnished to them in certain kinds of manure, it is to the atmosphere we must refer as the source whence it is supplied in the general abundance necessary for the uncultured vegetation diffused over the earth's surface. That it exists there in sufficient quantity for the purpose may be inferred from the decay of animal matter which is continually going on. The products which arise from this process present themselves in two different forms: in temperate and cold climates, they are in the form of ammonia—a combination of hydrogen and nitrogen;—and in the tropics and hot climates, they are in the form of nitric acid—a compound of nitrogen with oxygen and water. Ammonia is the last product of the putrefaction of animal matter; nitric acid is a product resulting from the transformation of ammonia. Reflecting that the whole population of the globe is renewed every thirty years, and that thousands of millions of animals cease to live, and are reproduced in a much shorter period, it may be fairly asked—Where is the nitrogen which they contained during life? No question can be answered with more certainty: it has gone to the atmosphere in the form of ammonia—in the form of a gas which is capable of entering into combination with carbonic acid, and of forming with it a volatile salt, which, like itself, is eminently soluble in water. In consequence of this property, ammonia cannot long remain in the atmosphere: every shower of rain must condense it, and convey it to the surface of the earth. Hence it is, that rain-water serves to nourish plants when distilled water will not: it must always contain ammonia, though not always in equal quantity. In summer it will be greater than in spring or in winter, because the intervals of time between the showers are in summer greater; and, when several wet days occur in succession, the rain of the first must contain more of it than that of the second. The rain of a thunderstorm, after a long protracted drought, ought for this reason to contain the greatest quantity which is conveyed to the earth at one time.

The ammonia which is thus removed from the atmosphere, must be constantly replaced by the putrefaction of animal and even of vegetable substances. A certain portion of that which falls with rain may also be supposed again to be evaporated; but another portion will be conveyed into the earth, and applied by the water which holds it in solution to the roots of plants to be by them taken up, and its nitrogen assimilated in the production of albumen, gluten, quinine, and a number of other compounds containing nitrogen as an element.

The analysis of grain grown upon lands differently manured affords the most convincing proof that the nitrogen of vegetables is derived from ammonia. Taking wheat as an example, we find the amount of gluten in different samples to differ very nearly in the ratio of the nitrogen contained in the manures supplied to the soil. This compound of nitrogen, which, it must be observed, is the truly nutritious part of flour, is invariably least when the manure is composed of vegetable matters, and greatest when the manure is animal debris. A difference has been observed of not less than 30 per cent. Specimens have been examined containing as little as $3\frac{1}{3}$, and as much as 35 per cent. of the azotized and nutritious compound.

The celebrated manure *guano* is now known to act only by the formation of ammonia. By means of it the barren soil on the coast of Peru is rendered fertile. "It is sufficient to add a small quantity of it to a soil which consists only of sand and clay, without the smallest particle of organic matter, in order to procure the richest crop of maize." Yet guano consists only of salts of ammonia and some earthy matters.*

Ammonia by its transformation furnishes nitric acid to the tobacco plant and sun-flower, when they grow in soils completely free of nitre. Nitrates (especially nitre) are necessary constituents of these plants—which thrive only when ammonia is present in large quantity, and when they are also subject to the direct rays of the sun, an influence necessary to effect the disengagement within their stems and leaves of the oxygen which is required to unite with the ammonia to form nitric acid.

From the facts related, it would further appear that the quantity of ammonia yielded to a soil is of less importance as a fertilizing agent than the form in which it is presented. Wild plants obtain more nitrogen from the atmosphere in the form of ammonia than they require for their growth; for the water which evaporates through their leaves and blossoms emits, after some time, a putrid smell—a peculiarity possessed only by such bodies as contain nitrogen. Cultivated plants also receive the same quantity from the atmosphere, as trees, shrubs, and other wild plants; but this is not sufficient for the purposes of agriculture. Agriculture differs essentially from the cultivation of forests, inasmuch as its principal object consists in the production of nitrogen under any form capable of assimilation, whilst the object of forest culture is confined principally to the production of carbon. All the various means of culture are subservient to these two main purposes. A part only of the ammonia, which is conveyed to the soil by rain, is received by plants; because a certain portion of it is volatilized with the vapour of water; only that portion of it can be taken up which sinks deep into the soil, is conveyed to the leaves by dew, or is directly absorbed from the air along with the carbonic acid. On the contrary, when the ammonia is presented in the form of manure, it is in combination, forming with certain acids which are always present in, or produced by such matters, fixed salts which are retained by the soil. The nutrient element is thus prevented from evaporating, and is moreover presented to the plant in the best form for absorption along with the mineral elements with which it is associated, and which, like nitrogen, seem essential to the complete development of the vegetable.

* Guano is collected from several of the South Sea Islands, upon the surface of which it forms a stratum of several feet in thickness. It consists of the putrid excrements of innumerable sea-fowl that remain on the islands during the breeding season.

NATURAL PHILOSOPHY AND CHEMISTRY.

CHAPTER XX.

ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART I.—VOLTAIC ELECTRICITY.—(*Continued.*)

105. THE researches of Professor Ohm have established, that the action of current electricity in any voltaic arrangement is directly as the electro-motive force, and inversely as the resistances which that force has to overcome. Ohm expresses these conditions by the following algebraic formula:—

$$A = \frac{n\,E}{r + n\,r'},$$

where A stands for the intensity of action, and E signifies the electro-motive force, which is independent of the superficial extent of the plates, the conducting power of the electrolyte, and the thickness of the liquid column.

n represents the number of alternations in the series. r' expresses the resistance of a single cell of the battery, which is dependent upon three conditions:—1st, the resistance increases directly as the thickness of the liquid volume; 2d, it decreases directly as the superficial dimensions of the conducting plates increase; 3d, it decreases directly as the conducting power of the liquid volume increases. r represents the resistance of the conducting substances external to the cells through which the current passes, such as the electrodes, the galvanometer, &c.

106. Nothing has so much tended to retard the progress of electrical discovery in this country as the general ignorance of Ohm's valuable researches, which prevailed until very recently. Even now, we fear it is but too true, that a large majority of talented cultivators of electrical science in Great Britain, are lamentably deficient in the knowledge of the investigations of continental philosophers; which is the more to be regretted when we reflect, that if Ohm's theory, combined with the mass of useful facts treasured in German and other foreign works, were more generally known and appreciated, and reasoned upon in this country, the student would be saved the unpleasantness of perusing the trashy speculations and theories with which many of our scientific publications abound, and be no longer mystified by conflicting statements—the natural results of investigations conducted without method, and entered upon in utter ignorance of such principles as those of Ohm, and others, to which we have briefly alluded.

107. We now come to the subject of volta-electric induction; but, before we enter into a detail of the various opinions of modern philosophers, as to the peculiar natural operation by which induction is produced, we shall explain the meaning of the term, and some of its most striking effects, or manifestations.

108. If a metallic ball, suspended by a silken thread, be charged by the electric machine, or, in other words, be supplied with more than its natural proportion of electricity—no matter by what means—and another ball, similarly suspended, be approached near it, a certain influence will be instantly exerted by the charged upon the uncharged ball, and will be manifested in two ways; 1st, by a tendency in the uncharged and charged balls to approach each other; and 2dly, by a peculiar condition being produced in that half of the uncharged ball farthest from the charged one, similar in all respects to the condition of the latter—that is to say, it will appear to possess upon that remote half more than the natural proportion of electricity that belonged to it previously to its approximation to the charged ball; and, on the other hand, that half nearest to the charged ball, will appear deficient in its natural quantity; but it can be proved that no additional quantity of electricity actually passed from the charged to the uncharged ball, but that the charged ball still possesses the identical extra proportion received by it previously to the approach of the uncharged ball. It become

evident, therefore, that some influence has been exerted, at a distance, by one ball upon the other, which has produced an alteration in the natural electrical condition of the uncharged ball—which change of condition invests that ball with a power of exercising a similar influence upon another uncharged ball approached to *it*, and so on through a series of uncharged balls, the influence, however, diminishing as the squares of the distance from the first ball. This influence, so exerted, without contact, by charged upon uncharged bodies, is called Induction.

109. But the disturbance of the electrical condition is not confined to the uncharged ball in the circumstances set forth in the preceding paragraph; for there appears to be a reciprocal action exercised by the uncharged upon the charged ball, by which the *plus* electricity which was, before the approach of the other ball, equally diffused over the surface of the sphere, is drawn in greater proportion to that half nearest the uncharged ball, and therefore presents an example of a body charged positively, exhibiting positive and negative conditions. This leads to the conclusion, that no inductive action is exercised by one body upon another, without a disturbance of electric equilibrium in both.

110. In the previous example we have assumed a case where one of the balls possessed more than its natural proportion of electricity, the other being in its natural state; but if, in place of accumulating electricity upon one of these balls, we deprive it of a portion of that which belonged to it naturally—which may be done by submitting it to an inductive influence, and while under that influence, touching with the finger that part where the electricity is *plus*—it will be found that this ball which is thus electrified *minus*, or, in other words, is deficient as to its natural quantity of electricity, will exercise an inductive influence upon the other ball, which is neither *plus* nor *minus*, but naturally electrified; and that also, in this case, the equilibrium in both will be similarly disturbed, that hemisphere of the *minus* ball facing the natural ball becoming more negative, and its remote hemisphere less negative, or more positive, while that half of the natural ball nearest the other, will assume a *plus* condition, at the expense of the remote part, which will necessarily become negative.

111. If two balls—one electrified positively, the other in its natural condition—be placed in contact, a certain proportion of superabundant electricity of the charged ball will diffuse itself over the uncharged one, until both become similarly electrified; in which case they may be considered as one mass, which will be in a positive condition in relation to surrounding bodies; and if, while so united, a third ball, uncharged, be presented to the others in such a manner as that its surface shall be equi-distant from both, induction will take place upon this ball, and the natural equilibrium of its electricity will be thus disturbed, as in the previous cases: with this difference, that the induced positive condition of the farthest part of the third ball will not be as high as if that ball had been only influenced by one of equal size with itself, charged with a quantity of electricity equal to that diffused over the two. Hence, it is apparent, that the influence of either of two bodies, unequal in size, but charged with an equal extra quantity of electricity, upon a third body, uncharged, will be in proportion to the respective masses; in other words, the inductive influence will be diminished as the mass is increased, the amount of charge being the same.

112. It is to be understood, that in each of the preceding examples, the balls employed are of the same metal, or same substance; and, it may be well to add, that in such experiments, the metallic balls should be always highly polished before use, but not lacquered; it being found in the course of various experimental investigations, that the system of lacquering, practised by most philosophical instrument-makers, greatly influences the results, especially in cases where accuracy is of the utmost importance.

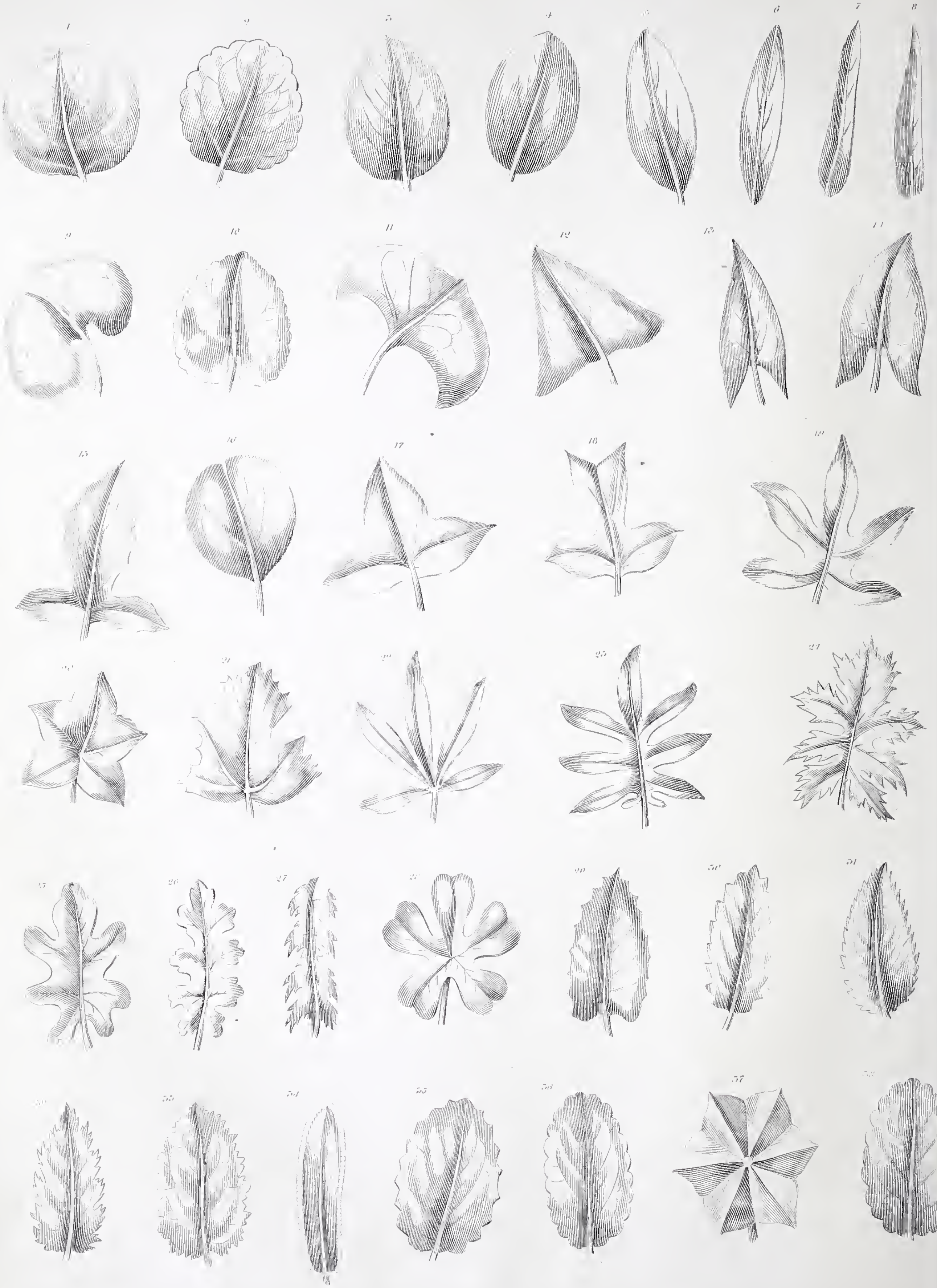
113. In the preceding examples, spherical bodies have been instanced, because, upon such bodies, electricity is known to be more equally diffused than upon others; the effects of external influences can therefore be more correctly ascertained. It has been found that the density of electricity upon a conducting body increases in a rapid proportion on approaching the edges, so that if a circular disk, or rectangular plate be employed, the electric density is only uniform on those parts not contiguous to its borders or edges. In a cylindrical conductor with hemispherical ends, in which all the edges are rounded off, the electric distribution is more uniform; but, unquestionably, for all purposes of experiment, a spherical conductor is the least objectionable.

114. The results of careful experiments have placed beyond a doubt, that inductive influence is as powerful *in vacuo* as *in pleno*. In the most perfect vacuum that has ever yet been obtained, a charged ball has been found to influence an uncharged ball at a considerable distance, with as much effect as if the experiment had been made in the atmosphere.

115. This fact brings us to the consideration of Faraday's recent researches on this subject, and thence to the supposed modes of propagation of the electric force through fluid media in voltaic arrangements. It may be collected, from what has been already stated, that induction takes place between bodies separated by greater or less intervals—by rare as well as dense media—by a vacuum, as well as by a plenum; and this without any loss or gain of electricity in either body, and, therefore, without the passage of any electric fluid between them. The question thence arises, how is this influence propagated?—by what means, or in what way, is the natural electric equilibrium of one body disturbed by the vicinity of another body or bodies invested with more than their natural definite proportion of electricity? Faraday answers these questions, by stating, as the result of elaborate investigations, that induction is propagated by an action of contiguous particles, forming a chain of communication between the inducing and induced bodies;—in other words, by a polarization of a line of interposed particles of matter; that particle nearest the inducing body being itself induced, and communicating its inductive influence to the particle next adjoining; and so on, from particle to particle, until the other body is reached, on which the original influence, thus propagated, is supposed to be expended. This view is supported by numerous experiments, which, however ingenious, do not satisfactorily explain many peculiar cases of inductive influence.

116. By "contiguous particles" Dr. Faraday does not mean, as he has been frequently supposed to do, that those particles are in absolute contact. He merely signifies proximate particles, or "those which are next to each other—not that there is no space between them;" and he assumes that insulating bodies consist of particles which are conductors individually, but do not conduct to each other, provided the intensity of action to which they are subject is below a given amount; and all insulating substances, or bodies whose particles are capable of undergoing polarization, or, in other words, of developing the two opposite electrical conditions—whether solid, liquid, or gaseous—are by him distinguished by the name of *dielectrics*.

117. As a proof of induction being an action, or rather an affection, of contiguous particles—a wide-mouthed glass vessel, having a perfect metallic communication through its bottom, was placed upon the prime conductor of an electrical machine, and filled with spirit of turpentine (a non-conductor), containing bits of white silk-thread about one-eight of an inch in length. Upon turning the machine, these threads were very slightly influenced, until a metallic conductor was presented near the surface of the liquid; but upon the approach of that body, motion was immediately perceptible amongst them; and, collecting from every point, they arranged themselves end to end, forming a line of communication from the conductor to the external metal, whose motions they were seen to follow in various directions. They again separated, as soon as discharge took place. Dr. Faraday considers the particles of air, or any other dielectric, to be similarly affected, although such polarized arrangements cannot, in most cases, be rendered apparent to the eye.



SIMPLE LEAVES.

BOTANY.

DEADLY NIGHTSHADE.

COMMON MEZEREUM.

POISON NUT.

SEVILE BITTER ORANGE.

AMYGDALUS COMMUNIS.

THE ALMOND TREE.

BOTANY.

CONIUM MACULATUM

COMMON HEMLOCK.

HELLEBORUS NIGER

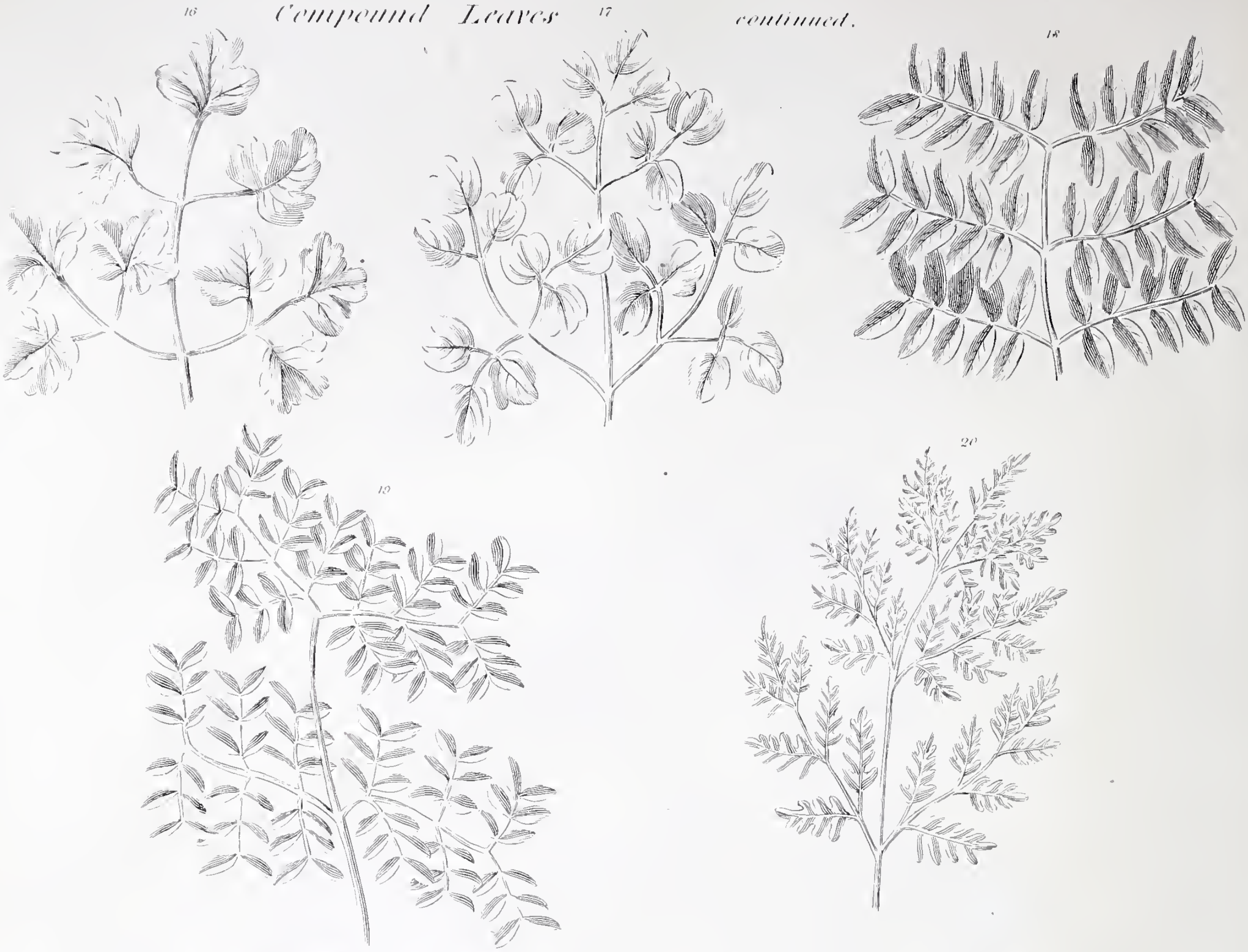
BLACK HELLEBORE.

NICOTIANA TABACUM

VIRGINIAN TOBACCO.

PLATE III.

Compound Leaves continued.



Disposition of Leaves.

Compound Leaves.

118. There appears much plausibility in the foregoing views; but, unfortunately, in applying them to the explanation of induction in every case, difficulties occur, which it appears to us almost impossible to surmount. For instance, if we are to suppose all arrangements of what Dr Faraday calls "contiguous particles" of ponderable matter to be similar in all respects to the arrangement of the silken threads in the liquid dielectric—that is, pole to pole, in a continuous chain—this molecular theory of induction might be conceived to hold good. But Dr Faraday himself admits the existence of greater or less intervals between the particles of the interposed dielectric; and in the case of a vacuum, he recognises the fact of induction occurring as well in empty as in full space, and intimates "that nothing in his theory forbids that a charged particle in the centre of a vacuum should act on the particle next to it, though that should be half-an-inch off." Now, surely, if inductive influence can operate from particle to particle, or from ball to ball, at the distance of half-an-inch *in vacuo*, there is nothing to prevent the same influence operating at the distance of half-an-inch *in pleno;* and in either, if the inductive influence can take a flying leap of half-an-inch from one particle to another, why should it not pass over the same distance from a charged to an uncharged ball, without the aid of intervening particles? It strikes us that, if, as has been proved in the case of a vacuum, a charged body is capable of influencing an uncharged one, without the intervention of contiguous particles, there can be no possible reason why induction should depend upon an action of contiguous particles in one case, and not in the other. If we are to assume any medium to be necessary for the propagation of an influence, why not recognise the existence of an universal ethereal principle undiscoverable by our limited powers of perception, but nevertheless omnipresent, and independent of matter? Such a medium might well be supposed adequate to propagate inductive as well as other influences, and would satisfactorily explain various disputed and unintelligible points in the modern theories of induction.

119. Dr Faraday has further ascertained, that different dielectrics possess different inductive capacities. This was proved by the employment of two metallic spheres, placed one within the other, and so arranged that the space between the two could be filled with either solid or liquid dielectrics, or even with gases. By such means, the capacity of different media for induction was investigated, with the aid of a Coulomb's electrometer and carrier ball. Dr Faraday subsequently employed an instrument which he called the Differential Inductometer, and he finally ascertained

The specific capacity of air to be	1
Of glass, ...	1·76
Of shell lac, . . .	2
Of sulphur, . . .	2·24

He further ascertained that all gases had the same capacity for supporting induction, and that no difference of density or elasticity caused a change in the electric intensity, until they became rarefied to such a degree as to admit of discharge taking place across them. Dr Faraday also states that he has found that induction is not, as was previously supposed, alone propagated in straight lines; but that, when a body offering resistance to induction is placed upon an excited body, so as to interfere with the exercise of the inductive influence upon another body in a direct line, that influence will be propagated by curved lines, so as to cause the induction to pass round the edge of the screen interposed between the excited and induced body; and that, if a number of uncharged balls be placed in different positions in relation to the excited substance, each ball will propagate its inducing influence, not only in one direction, but laterally or obliquely, according to the relative position of the other balls.

120. We shall now see how far the foregoing views and principles, connected with static electricity—for most of which we are indebted to the researches of Dr. Faraday—have been applied by him and others to the explanation of certain phenomena attendant upon voltaic or current electricity. Without the foregoing details, it was judged impossible for the reader to comprehend clearly the modern views of induction, as applied to voltaic and electro-magnetic action. With many of those views we cannot agree; but, in a treatise designed to afford a general idea of the present state of these sciences, it would be improper to omit opinions entertained by some distinguished philosophers of the present day, and based, to a certain extent, upon the results of experimental researches.

BOTANY.

CHAPTER II.

STRUCTURE OF PLANTS.

The various parts of which a plant is composed are termed its *organs*; and this term is equally applied to those external parts which appear distinctly separate even to the careless observer, and to more delicate apparatus, unravelled only by dissection. It is applicable to all those parts which are obviously subordinate to the whole, such as leaves, roots, flowers, and fruit, and to certain minute cells, and tubes, and fibres, of which its internal structure consists.

The external organs are sufficiently familiar to every one, and may be grouped under two heads, obviously separated by the nature of the functions which they are called on to perform. The root, stem, branches, and leaves, with some other smaller appendages to each of them, are formed for carrying on the processes of nutrition, being subservient to the growth of the plant, and are consequently styled the *conservative* organs. The flower and fruit, with their appendages, are intended for performing the function of reproduction, being subservient to the continuation of the species, and are therefore called the *reproductive* organs.

The conservative organs are arranged in two sets, one descending into the ground, the roots, and spreading themselves there, for the purpose of sucking up nourishment; the other set ascending, above the ground, the stem and branches, with the other parts which they support. This division is not, however, strictly correct, for the Banyan tree sends down roots from its branches, which by and by fix themselves in the earth, but have still been roots all the time they were hanging in the air; while other plants, as the Bugle, have their stem creeping along the surface of the ground, or even under it, before rising perpendicularly. The distinction, as above stated, is however generally applicable.

The reproductive organs also may be arranged in two series,—those which compose the *inflorescence,* that is to say, the flowers and their appendages; and those which are included under the term *fructification;* that is, the seed and its coverings, which we term the fruit. Here, too, our definitions do not apply with perfect exactness, for the Cryptogamic plants have no flowers nor seeds, but are propagated by *sporules,*—little grains which have the same use, but are totally different in structure from true seeds. In the remainder of this article we shall devote ourselves to the examination of the internal structure of plants; and, before describing organs, we shall look at the nature of the elementary tissues. In these there is a great simplicity as compared with the tissues of an animal body, in whom each function which is to be performed seems to need an organ specially adapted for it; while, in plants, a few simple tissues appear to be all that is required. This simplicity is perhaps, however, over-estimated.

Every plant, and every part of a plant, consists of solids and fluids intermixed; the solids being, however, in much greater proportion than in an animal body. Cut a succulent plant across—as the stem of a cabbage—and even with the naked eye a number of *cells,* exuding fluid, will be seen; with the help of a microscope a regular network of hexagonal meshes will be brought into view, smaller and less regular where they surround vessels (tubes), as seen in the

accompanying figure. If, on the other hand, the section be made lengthways, the cells will appear quadrilateral, compressed, and elongated in the direction of the stem, and still smaller and narrower where they surround vessels. By *vessels,* beginners must be told we mean tubes—generally very small, sometimes straight, but oftener twisted or coiled. In the lowest classes of plants, no vessels can be detected, their structure seeming to be altogether cellular. We have here these examples of the two *elementary* tissues which we call *fibre* and *membrane,* out of which all other tissues are constructed.

Fig. 5.

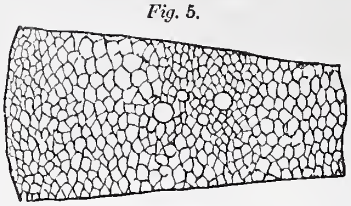
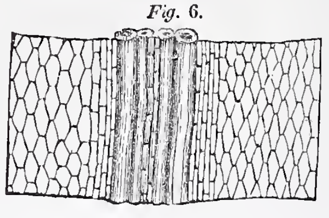


Fig. 6.



In regard to chemical composition, vegetables consist of oxygen, hydrogen, and carbon, and in many cases, a minute portion of nitrogen. Various vegetable products, differing very much in their sensible qualities, often present to the inquiring chemist a very slight difference in the proportion of their several constituents; so that one is apt to wonder how their taste, and smell, and effects on animal bodies, are so different. As is the case in animal bodies, the several chemical constituents are held together by very slight affinities, apparently altogether as a consequence of being inspired with life; so that whenever that life is withdrawn, they pass with great rapidity into a state of decomposition.

In the actual anatomy of plants, we find the membranous and fibrous elementary tissues showing themselves under the forms of cellular tissue, woody tissue, and vascular tissue.

It is almost certain that all these forms are but modifications of simple cells, however different from each other they may become, in station, function, or appearance. A good reason for believing this is, that all organs are developed from a rudiment which at first consisted of nothing else but cellular tissue; for every seed is at first just an aggregation of cells, though, after its vital principle has been excited, and it has begun to grow, woody fibres and vessels are generated in abundance. We must, therefore, either admit that all forms of tissue are developed from the simple cell, and are consequently but modifications of it; or we must suppose, what we have no right to assume, that plants have a power of spontaneously generating woody and vascular tissue in the midst of the cellular.

Let us take a brief look at these three tissues, and their modifications.

Cellular tissue appears to consist of little bladders or vesicles, of various figures, adhering together in masses, composed of membrane and fibre, transparent and colourless; its colour, when it appears to have any, being caused by something contained within it. If a thin slice of the pith of the Elder, or any similar plant, be examined with a sufficient magnifying power, it will be found to have a sort of honeycomb appearance, as seen in fig. 5, consisting of cavities, separated by partitions. These little cavities are the bladders of cellular tissue, and the partitions are caused by the adhesion of their sides. These bladders are destitute of all perforations or visible pores, so that each is closed up from its neighbour; though, as they have the power of filtering fluids rapidly, as explained at the end of this article, it is certain that they must abound with invisible pores, and are not impermeable, as if made of glass. As an illustration of this subject, it may be remarked that the limits of colour are often very accurately marked in flowers, as the stripes of tulips and carnations; which could not be the case if their cellular tissue were freely perforated, for in that case the colours would necessarily run together.

The cellular tissue, it has been said, is transparent and colourless, or at most only slightly tinged with green. The clear satiny lustre which the surfaces of many rich flowers exhibit, depends on this colourless quality. In some, as in species of the garden Balsam, a brilliant scarlet cell will be seen in the midst of a colourless flower-leaf; and, if it be properly examined, it will be found filled with a colouring matter of which the surrounding cells are destitute. These bladder-like cells are developed, in some cases, with great rapidity. Professor Lindley says he has seen the *Lupinus polyphyllus* grow in length an inch and a half a-day; and that another observer states the leaf of the *Urania speciosa* to have lengthened from $1\frac{1}{2}$ to 3 lines per hour, and even as much as 4 or 5 inches per day. This may be computed to equal the development of at least 4000 or 5000 bladders in the hour! These bladders or cells are always very small, but are exceedingly variable in size. The largest are generally found in the Gourd tribe, or in pith, or in water plants; and of these, some are as much as $\frac{1}{30}$th of an inch in diameter, their ordinary size being about $\frac{1}{300}$th or $\frac{1}{500}$th, and sometimes not more than $\frac{1}{1000}$th. These microscopical measurements must all, however, be taken with some degree of allowance.

It would appear that the spheroid (7) is the original form of the cell, and that it becomes altered in its varied situations, so as to accommodate itself to its neighbours, and to the uses for which it is designed, so as to be oblong (8) or clongated (9).

Fig. 7.

Fig. 8.

Fig. 9.

If we suppose a piece of cellular tissue, consisting of rounded cells, to be compressed, the cells will plainly become, as in a honeycomb, hexagonal (10), because six equal circles can touch a seventh which is in the centre. Of course, when the cells are unequal, this regularity is lost. Instead of looking at their cut edges, and considering them as circles, or hexagons, if we take them to be spherical bladders or cells, we will find that one cell may become the centre, round which twelve others can be ranged, of equal size, all in contact with one another (11); and if these be subjected to pressure, each sphere will be compressed into a *dodecahedron,* or figure with twelve sides and eighteen angles, of which three varieties are given—the rhomboidal (12), the clongated (13), and the flattened (14).

Fig. 10.

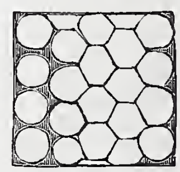


Fig. 11.

Fig. 12.

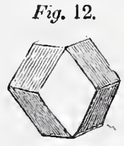
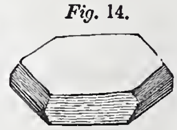


Fig. 13.

Fig. 14.



Many vegetable anatomists consider *woody tissue* to be a mere form of cellular tissue in an elongated state. Still, according to Lindley, it would seem to be different. Generally, while cellular tissue is brittle, and has little or no coherence, woody tissue has great tenacity and strength; whence its capability of being manufactured into linen. Everything prepared from flax, hemp, and the like, is composed of woody tissue; but cotton, which is cellular tissue, bears no comparison, as to strength, with either flax or hemp. Woody tissue consists of fibres, and the fibres, when separated for making thread, are by no means in a state of final separation—each of the finest that meets the eye, being in reality a

bundle of others, often six times finer than the finest human hair. Even these very finest ones are considered to be really tubes, varying from $\frac{1}{150}$th to $\frac{1}{3000}$th of an inch in diameter. Woody tissue forms a considerable share of the woody part of all plants: it gives the stringiness to bark, and the tenacity to the veins of the leaves. There can be little doubt that it consists of compressed cells. Its chemical constituent is carbon, which it affords plentifully by being charred.

Vascular tissue consists of small membranous tubes or vessels, having the power of transmitting the fluids of the plant for the purpose of its nutrition. We can easily have an idea of the mode of their formation, if we suppose a series of elongated cells to open into one another, as seen in the accompanying fig. 15. These vessels are generally spiral, sometimes one vessel running by itself, (fig. 16,) with greater or less intervals between its turns, and sometimes two (fig. 17), three, or four (fig. 18) running together. Through

Fig. 15.

Fig. 16.

Fig. 17.

Fig. 18.

these spiral vessels, and probably also through the tubes of the woody tissue, the fluids on which the plant is nourished are drawn up from the ground. Then they pass into the leaves, in order to be exposed to the air, where they give off a portion of oxygen, and absorb a portion of carbon, and afterwards descend in the true sap-vessels, which run in the inner bark, for the purpose of nourishing the plant, and causing it to grow, that a new layer may be added to the stem, over the old, just beneath the bark. Thence, when growth is necessary elsewhere, the sap arrives at the place by permeating the cellular tissue of the medullary rays, which will be explained in a future article. The sap is constantly flowing through a plant, except during the time of frost; but it increases in spring—becomes very copious in summer—and in the autumn again gradually diminishes. Although plants have not a circulation like that of animals, the same fluid constantly departing from, and returning to, a central point, still their fluids have a motion which often presents extreme rapidity. This is proved by the great quantity of water which they perspire—all of which must be replenished by a new supply passing in rapid motion from the roots along the vascular and woody tissues. A young vine-leaf is said to perspire so copiously, that, if a glass be placed next its under surface, it is presently covered with dew, which in half-an-hour, runs down in streams. Hales, who devoted so much time to physiologieal investigation, found a sun-flower lose one pound four ounces, and a cabbage one pound three ounces, in a day, by perspiration.

It is a very curious thing, that the sap does not begin to run from the earth in the spring, and so *push* on what was before in the vessels into the buds, but the small quantity which was in the end of the braneh is *drawn* into the bud; a vaeuum is thus created, which is filled by the sap below, and so the process goes on, backward, until a draught is made upon the moisture of the surrounding earth.

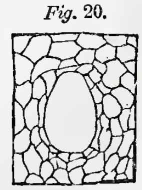
The *cause* of the movement of the sap seems to be a galvanic or electrical action. Dutrochet found that small bladders of animal or vegetable membranc being filled with a fluid of greater density than water, and then thrown into water, aequired weight; he also remarked, that if the experiment were reversed, by filling them with water, and immersing them in a dense fluid, they lose weight. He took a small bladder, and filled it with milk, or gum-water; to its mouth he adapted a tube, and then plunged the bladder in water; in a short time he found that the water rose in the tube, showing that water had been attracted through the sides of the bladder. The reverse was also tried, and the fluid fell in the tube. From these, and other similar experiments, Dutrochet arrived at the conclusion, that if two fluids of unequal density be separated by an animal or vegetable membrane, the denser will attract the less dense, through the membrane that separates them, and this property he called *endosmose*, when the attraction is from the outside to the insidc; and *exosmose*, whcn it operates from within outwards. In pursuing this investigation, hc remarked, that if an empty bladder be immersed in water, with the negative pole of a galvanic battery in it, while the positive pole is in the water which surrounds it, a passage of fluid takes place through the membrane, as had previously happened when the bladder contained a fluid denser than water; and by reversing the poles, the reverse was found to take place. From all this, Dutrochet deduces the following theory, as expressed by Lindley:—"That when two fluids of unequal density are separated by an intervening membrane, the more densc is negatively electrified, and the less dense positively electrified; in consequence of which, two electric currents of unequal power sct through the membrane, carrying fluid with them; that which sets from the positive pole, or less dense fluid, to the negative pole, or more dense fluid, being much the more powerful; and that the fluids of plants being more densc than those which surround them, a similar action takes place between them and thc water in the soil, by means of which the latter is continually impellcd into their system. Philosophers do not seem disposed to admit the legitimacy of Dutrochet's conclusion, that this transmission takes place by means of galvanic agency; but that the phenomenon is correctly described by the ingenious author, and that it is constantly operating in plants, is beyond all dispute. It will, perhaps, be found the most ready explanation of most of the phenomena connected with the movement of fluids in plants."

The *vital vessels*, (fig. 19), analogous to our arteries, which are situated in the inner bark, close to the wood, present a different appearance from those in which the sap rises; they communicate sideways, or *anastomose* frequently with one another: and in some plants, with the help of the microscope, the juices may be seen in currents consisting of a succession of globules flowing very rapidly through them.

Fig. 19.

The *cells* of plants are filled with juices, which distend them, and make them stiff and firm; and it is from the evaporation of these juices, without any new supply, that the leaves and stem droop, a few hours after being plucked. The stiffening effect of the water again distending them, is seen in a bouquet of flowers, which will droop before they havc been got home from a walk, but revive and hold themselves up, soon after their stems have been put in a glass of cold water. These juices have particular qualities, as colour, taste, and smell, distinguishing thcm in different vegetables. But in addition to these, many plants havc *proper vessels*, or *receptacles* of secretion, in which particular fluids are contained, filled with the *proper juice* of the plant, *i. e.*, with its sap altered to the state which is peculiar to the particular species producing it. They seem generally to be formed by the dilation of one cell, at the expense of its neighbours, which it compresses, as the little oblong or round cysts in the rind of the lemon and orange, (fig. 20,) which every one has seen, and known to contain a pungent and inflammable essential oil. Many of the plants which grow in water, have cells of this kind filled with air, which serve the

Fig. 20.



purpose of swimming-bladders, enabling their stems to float, so that their parts of fructification may be exposed to the air, resting on the surface of the water.

GEOLOGY.

CHAPTER XV.

NEW RED SANDSTONE OR SALIFEROUS SYSTEM.

The history of the earth, as developed in those monuments of the organic kingdom which are met with in its stratified rocks, may be considered as divisible into three grand epochs. The first, or most ancient, comprises the space of time which elapsed from the deposition of the non-fossiliferous slates to the termination of the coal formation, including the silurian, old red sandstone, and the carboniferous rocks, in which the only trace of vertebrated animals is confined to fishes; a few insects are the only animals fitted for atmospheric respiration discovered. The secondary period, including the saliferous, liassic, oolitic, and cretaceous systems, presents a greater number of vertebrated animals, consisting chiefly of aquatic and a few terrestrial reptiles. Besides these animals with aerial respiration and cold blood, only one genus of mammalia and many insects are the creatures which alone appear to have existed on the land. The third, or tertiary epoch, includes all the deposits, from the chalk to the erratic boulders. In this epoch we have a near approach to the present order of Nature in the existence of vast numbers of extinct mammalia, and a gradual increase of the existing species of mollusca. The present period is that characterized by the creation of man and those terrestrial animals which appear to have been called into existence at nearly the same time.

In the preceding chapters we have endeavoured to acquaint the reader with the phenomena, organic and inorganic, of the first great epoch; and we now proceed to the consideration of the second, commencing with the deposits of the new red sandstone or saliferous system.

The latter term has been given to the earliest group of secondary deposits, from the circumstance of its being the great depositary of rock salt in England, but the appellation is highly irrelevant; for, if this condition in other countries were to form the basis of a geological nomenclature, other systems would be equally entitled to the name: as beds of rock salt are met with in the old red sandstone of Russia, and the oolitic rocks of the Alps; whilst the salt mines of Cardona in Spain belong to the green sand of the chalk formation, and those of the Wieliezka, at the foot of the Carpathian mountains, occur in the tertiary beds, and the salt springs of Durham, Northumberland, and Leicestershire, rise from the coal formation.

The term Poikilitic (from ποίκιλος, varied; λίθος, a stone) has been proposed by Mr Conybeare as that by which it should be designated; but the English term, new red sandstone, we regard as equally significant.

The following synopsis gives the general character of the different groups or members into which the system is divided, commencing with the newer formations:—

UPPER RED SANDSTONE GROUP.

1. *Variegated Marls.*—(The Keuper Grits of Germany.)—These consist of red, bluish, greenish, and whitish clays or marls, containing gypsum and rock salt. Included in these marls are certain white and grey sandstone, considered as the equivalents of the German Keuper grits.

2. *Muschelkalk.*—(*Shell Limestone.*)—This is a gray compact limestone abounding in marine remains.

3. *Variegated Sandstone.*—(The Bunter Sandstone of the German, and Gres Bigarré of the French.)—Consisting of beds of red sandstone, in some places mottled or conglomeratic.

MAGNESIAN LIMESTONE GROUP.

1. *Upper Limestone.*—(The Stinkstein and Rauch-wacke of the Germans).—A fetid and laminated limestone, alternating with beds of coloured marls.

2. *Gypseous Marls.*—Red, bluish, and variously coloured marls, with gypsum.

3. *Magnesian Limestone.*—(The Zechstein of the Germans.)—Limestone composed of carbonate of lime and carbonate of magnesia, of varied structure, and of a white or yellowish colour.

4. *The Marl Slates*—(The Kupfer Schiefer of Germany.)—Impure calcareous rocks of a sandy or clayey nature.

5. *Lower Red Sandstone or Conglomerate.*—(The German Rothlegende, and the Gres de Vosges and Gres Rouge of the French.)—Red sandstone and conglomerates, with red marls and micaceous laminated sandstones.

Organic Remains.—Organic remains are rarely met with in rocks where red is the prevailing colour; accordingly they are rare in the English deposits of the new red sandstone; and such as do occur are chiefly met with in the magnesian limestone. The Muschelkalk of Germany, however, abounds with new and extraordinary forms of animals, which seem to have perpetuated their species through nearly the whole period of secondary deposition, and on slabs of red sandstone found in several places we have preserved the footprints of gigantic birds, and Batrachians or Toads of strange configuration, and no less wonderful dimensions. An account of the principal remains of the formation cannot fail to be interesting.

Plants.—The older deposits contain the remains of ferns, calamites, lepidodendra, &c., plants similar, if not identical, with species found in the coal formation; but these disappear in the newer beds, in which a variety of coniferous plants, allied to the Auracaria, termed Voltzia, after the discoverer M. Voltzia, have been found.

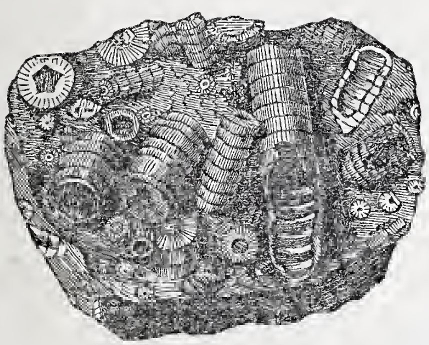
Six species of fuci or seaweeds have been discovered in the new red sandstone, and plants allied to the cycas, a class intermediate betwcen the ferns and the palms, appear for the first time.

By what agency, it may be asked, was the immense vegetation of the coal era swept away from the surface of the earth? There is every evidence in many of those districts where the red sandstone is superimposed upon the coal beds, of great disturbances having taken place between the two periods of deposition. In England the strata of the two repose in unconformable positions, and the lower portion of the red sandstone is often a conglomerate. In some places of Ayrshire, in Scotland, the red sandstone and the coal measures are separated over considerable tracts by volcanic taffa of the same character as some of the volcanic layers which constitute the trap rocks of the Gleniffer range near Paisley, which is easily identifiable with that of the Kilpatrick and Campsie hills on the north of the Clyde; and, indeed, with the great mass of trap traversing and covering large portions of the carboniferous series throughout the counties of Stirling, Dumbarton, Renfrew, Lanark, and probably the islands of Cumbray, Bute, and Arran, in the estuary of the Clyde. To the latter supposition it may be objected, that the trap rocks of Arran are newer than the conglomerates and new or upper red sandstone of that island, and therefore cannot be of the same age as volcanic deposits resting immediately on the carboniferous series of Ayrshire; but, it ought to be remembered, that the deposits which overlie the carboniferous limestones containing the oldest Producta of the series, namely, the gigantea and hemispherica, cannot be regarded as otherwise than contemporaneous deposits with the coal beds, and their associated strata of the main land—an unbroken continuity of deposition being quite evident from the limestone to the newest deposits of the island. We have little doubt, therefore, that what may be really termed the new red sandstone of Scotland, namely, that portion of it which occurs in the parish of Auchinleck, and other places in Ayrshire, but not the beds of red rock which are identifiable elsewhere with the coal measures, was deposited after a period of great igneous disturbance in these islands, the effects of which may have been to alter materially

the conditions of the surface, and sweep from it the luxuriant vegetation with which it had hitherto been adorned; but not only did the land undergo general changes, but the gigantic megalichthys, and other enormous fishes, seem to have perished in the ocean,—the fresh water estuaries, in which they appear to have delighted, giving place to a wide and turbulent expanse of oceanic waters bubbling with the smoke of submarine volcanoes, and extinguishing all trace of former marine life with their noxious effluvia. How far the red colour of the sandstones and shales of the saliferous rocks is due to the influence of volcanic action is a problem well worthy the attention of geologists.

Crinoideans.—In our account of the carboniferous system, we have had occasion to refer to a class of zoophytes, which performed a very important part in contributing to its calcareous formations. These are very much allied to certain species of star-fishes, which are furnished with long flexible arms, and which, if provided with a stalk, would afford a tolerable likeness of the animals in question.

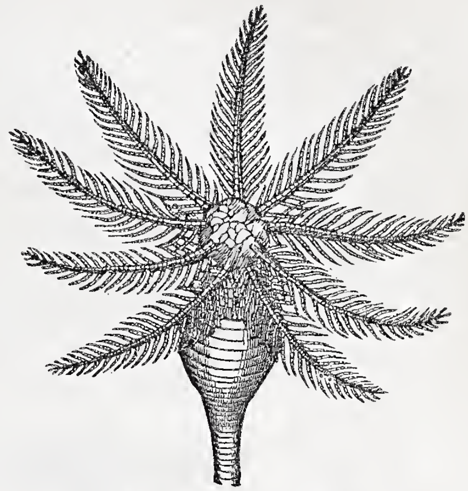
The Crinoideans, or lily-shaped animals (from *κρίνον* a lily, and *εἶδα*, a shape or form,) lived fixed at the bottom of the sea. In the carboniferous era, large tracts of it must have been covered with them, as limestone extends over areas of many square leagues, which in numerous instances are almost entirely composed of their remains. Vast quantities of them are also found in the shales which overlie the limestone beds. These remains consist chiefly of small circular radiated calcareous plates, perforated in the centre, or of portions of the stem on which many are joined together. The cup, or pear-like shaped body to which the arms are attached, is rarely found entire. The manner in which the remains occur in limestone is shown in the following cut, made from a small slab of the encrinal marble of Derbyshire:—



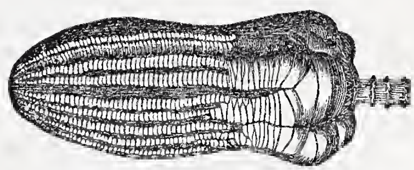
The little beautiful radiated plates, the Entrochi, or wheel-stones of the old naturalists, and fairy beads of the Scottish peasantry, are variously striated and indented according to the different species or genera to which they belong. The classification of them has chiefly devolved on Mr Miller, who, in his valuable work on the Crinoideæ, has entered very minutely into their natural history and distinguishing characteristics. His general description of the family is as follows:—

"An animal with a round, oval, or angular column, composed of numerous articulating joints, supporting at its summit a series of plates or joints, which form a cup-like body, containing the viscera from whose upper rim proceed five articulated arms, dividing into tentaculated fingers, more or less numerous, surrounding the aperture of the mouth, situated in the centre of a plated integument, which extends over the abdominal cavity, and is capable of being contracted into a conical or probosal shape."

The Crinoideans, which have 5-angled plates or stems, are termed Pentacrinites, one species of which still exists in the bottom of the Carribbean Sea. It is known in our museums as the Pentacrinus Caput Medusæ. Another stemless variety is also met with in the present ocean, known by the names of the Pentacrinus Europeus, and Comatula fimbriata. The Lily Encrinite, which occurs exclusively in the Muschelkalk of the new red sandstone, is one of the most beautiful



Apinocrinites rotundus, with the arms expanded.



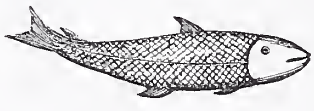
Encrinus moniliformis, or Lily Encrinite, with the arms closed.

varieties of this interesting family. The small plates or ossicula which occur in a single animal are estimated by Parkinson as amounting to 26,000, while the number of bones in another variety, the Briarian pentacrinite of the lias formation, according to Dr Buckland, was no less than 100,000. The Doctor remarks, that if to these we add 50,000 more for the ossicula of the side arms, which is much too little, the total numbers will exceed a hundred and fifty thousand; and as each bone was furnished with at least two fasciculi of fibres, one for contraction, the other for expansion, we have a hundred and fifty thousand bones, and three hundred thousand fasciculi (bundles) of fibres equivalent to muscles, in the body of a single Pentacrinite, an amount of muscular apparatus concerned in regulating the ossicula of the skeleton exceeding any that has yet been observed throughout the entire animal kingdom. The physiological history of these Crinoideans is thus very important. Their species were numerous among the most ancient orders of created beings, and in this early state, their construction exhibits at least an equal, if not a higher, degree of perfection than is retained in the existing Pentacrinites; and although the place which as zoophytes they occupied in the animal kingdom was low, yet they were constructed with a perfect adaptation to that low estate; and, in this primeval perfection they afford another example at variance with the doctrine of the progression of animal life from simple rudiments through a series of gradually improving and more perfect forms to its fullest development in existing species. Thus a comparison of one of the early forms of the genus Pentacrinite, the Briarian Pentacrinite of the lias, with the fossil species of more recent formations, or with species from the Carribbean Sea, shows in the organization of this very ancient species an equal degree of perfection, and a more elaborate combination of analogous organs than occurs in any other fossil species of more recent date, or in its living representatives.

Fishes.—The fishes of the new red sandstone possess considerable interest, as the genus to which they chiefly belong, viz., the Palæoniscus, is very distinctly distributed in both the rocks of that and the carboniferous system. The spe-

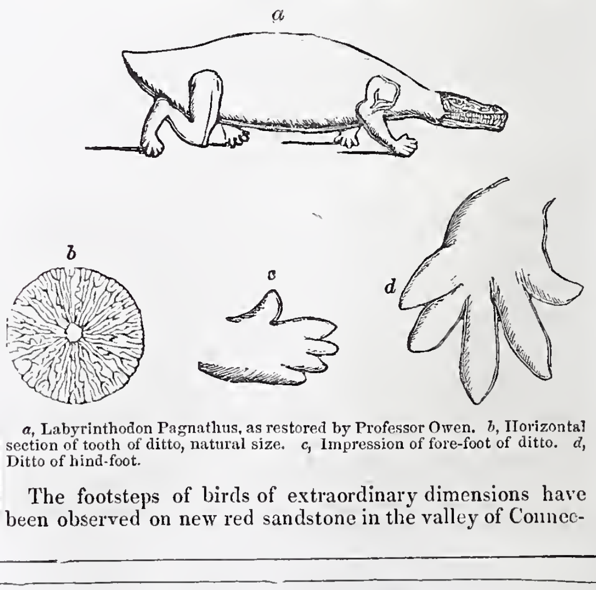
cies, however, are different; the scales of those found in coal formations are smooth, while those in the magnesian limestone are striated or sculptured. There are exceptions, however, to this rule, in the Palæonisci from the Burdie-house limestone near Edinburgh, and from Ardwick in the neighbourhood of Manchester. Twenty species of this genus are enumerated as having been examined by Professor Agassiz, of which three are from the carboniferous limestone, seven from the coal formation, five from the magnesian limestone, three from the Zechstein, and two from the lower red sandstone, or Rothlegende of Germany. It is worthy of notice that Agassiz failed to identify any of the species of the English magnesian limestone with those of the Zechstein, notwithstanding they are supposed to be contemporaneous formations. This cannot however excite the least surprise, or place the contemporaneity of the formations in doubt, because it is not rare in the present distribution of fishes to find quite different species of the same genus existing in different regions not more remote than the English and the German deposits are.

The generic character of the Palæoniscus, is as follows:—all the fins of moderate size with small rays on their edges, the dorsal or back fin opposite the ventral or belly and anal fins; scales moderate, enamelled and rhomboidal. In some the scales are large, and the body shorter and broader. The annexed cut gives the general appearance of the genus.



Palæoniscus Robinsonia.

Fossil foot-prints.—A few years ago, Dr Duncan gave an account, in a paper read before the Royal Society of Edinburgh, of the tracks and footmarks of animals on a new red sandstone in the quarry of Cockle Muir, near Dumfries. The sandstone was laminated or flaggy, and the foot-prints quite observable in many of the flags to the whole depth to which the sandstone had been worked, which was about forty-five feet; "for, after removing a large slab which contained foot-prints, they found perhaps the very next stratum at the distance of a few feet, or it might be an inch, exhibiting a similar phenomenon. Hence it follows, that the process by which the impressions were made on the sands, and subsequently buried, was repeated at successive intervals." Other impressions of the same kind were subsequently observed about ten miles south of Corncockle, in the red sandstone quarries of Craigs, two miles east of the town of Dumfries. "The foot-prints traverse the rocks in a direction either up or down, and not across the surface of the strata, which are now inclined at an angle of 38°. On one slab, there were twenty-four continuous impressions of feet, forming a regular track, with six distinct repetitions of the mark of each foot, the fore-foot being differently shaped from the hind-foot; the marks of the claws are also very distinct. On comparing," continues Dr Buckland, "some of these impressions with the tracks which I caused to be made on soft sand and clay, and upon unbaked pie crust, by a living Emys, and Testudo Cræco, (varieties of the tortoise,) I found the correspondence sufficiently close, allowing for difference of species, to render it highly probable that the fossil footsteps were also impressed by the feet of land tortoises." Fossil foot-prints have since then been observed in Saxony, similar to those of Dumfries, in red sandstone of the saliferous system; but along with this were the foot-prints of another animal, whose character, till lately, has been a source of great perplexity to the Naturalist. The impressions, according to Dr Buckland, of the feet are partly hollow, and partly in relief. All the depressions are upon the *upper* surface of slabs of sandstone, whilst the relief are only on the *lower* surfaces, covering those which bear the impressions. These reliefs are natural casts, formed in the adjacent footsteps as in moulds. On one slab. six feet long by five feet wide, there occur many footsteps of more than one animal, and of various sizes. The larger impressions, which seem to be of the hind foot, are eight inches long, and five wide. These footsteps follow one another in pairs, at intervals of fourteen inches from pair to pair, each pair being in the same line. Both large and small steps have the great toes alternately on the right and left side; and the first or great toe is bent inwards, like a thumb. The fore and hind foot are nearly similar in form, though they differ so greatly in size. On the same slab are other tracks of smaller and differently formed feet, armed with nails. Many of these resemble the impressions on the sandstone of Dumfries, and are apparently the steps of Tortoises. Similar impressions to the larger, and also of five or six smaller reptiles, have recently been discovered in the new red sandstone of Cheshire, Warwickshire, and Salop; and by Mr Cunningham at Storetown Hill, on the west side of the Mersey, near Liverpool. Mr Cunningham also describes impressions on the same slabs with them, derived from drops of rain that fell on the thin laminæ of clay interposed between the beds of sand. The clay, impressed with these prints of rain-drops, acted as a mould, which transferred the form of every drop; so that the entire surface of strata in the same quarry are respectively covered with moulds and casts of drops of rain that fell whilst the strata were in the process of formation. Nor is it a little singular that on the surface of one of the slabs on which the large hand-like impressions are made, these rain-drops are also observable on the spots imprinted by the foot of the animal; and that "the depth of the holes, on different parts of the same footstep, has varied with the unequal amount of pressure on the clay and sand by the salient cushions and retiring hollows of the creature's foot; and, from the constancy of this phenomenon, where are an entire series of footmarks in a long continuous track, we know that this rain fell after the animal had passed." The name of Chirotherium (handed wild beast) was given to the animal to whom the larger footprints belonged, and it was supposed to have been allied to the kangaroo tribe; but the anatomical researches of Professor Owen have shown it to have belonged to a gigantic genus of extinct Batrachians or Frogs, and identical with the Mostodonsauras and Phytosauras found in the Keuper grits of Germany; to which, with several other species belonging to the new red sandstone, he has given the generic name of Labyrinthodon, from the labyrinthic structure of the teeth when examined by the microscope. But, for farther information on the anatomical structure and character of these singular and gigantic reptiles, we must refer to a very excellent article, under the word Salamandroides, in the *Penny Cyclopædia*, from which we copy the following cut. The size of one of the species may be conjectured from the fact that one of the teeth measures $3\frac{1}{2}$ inches in length, and $1\frac{1}{2}$ inches in diameter.



a, Labyrinthodon Pagnathus, as restored by Professor Owen. *b*, Horizontal section of tooth of ditto, natural size. *c*, Impression of fore-foot of ditto. *d*, Ditto of hind-foot.

The footsteps of birds of extraordinary dimensions have been observed on new red sandstone in the valley of Connec-

ticut, in the United States of America. They appear to have been waders, and to have far surpassed in magnitude any species of bird now existing on the surface of the globe. The impressions are most distinct, and occur with those of many others of smaller species.

Saurians.—In the copper schists of Thuringia, in Germany, besides the remains of fishes, there were found the remains of a reptile, which Cuvier considered allied to the living genus of the moniter, a tropical lizard, which frequents marshes and the shallow beds of rivers; and the remains of three other species of fossil saurians were discovered by Dr Riley and Mr Samuel Stutchbury, in the magnesian conglomerate of Durdham Downs, near Bristol, in the year 1834—two of which belong to the genus Palæosaurus (παλαιῶ, antiquated, and σαῦρος, a lizard); and the other has been named the Thecodontosaurus, from the teeth being implanted in distinct sockets, either loosely or confluent with the walls of the cavity (from θήκη, a box or case; and οδοντος, a tooth). The microscopic structure of the teeth of the thecodont corresponded with that of the living moniter. The teeth of the palæosaurus are laterally carniated, and finely serrated—a structure which differs from that of any known Saurian. The vertebræ, like those of fishes in both genera, are doubly concave; whereas, in other fossil and recent crocodiles, they are anteriorly convex. The same doubly concave structure is found in the vertebræ of the fish-lizard, which began to exist towards the close of the new red sandstone period—a conformation by which they were better adapted for aquatic existence, and which may be regarded as the oldest type of vertebral structure. The remains of two other Saurians, the Rhynchosaurus and the Cladyodon, have been discovered—the first in the new red sandstone of Shropshire, and the latter in that of Warwick and Leamington.

From these details it appears that the fossils in the new red sandstone, although numerically less than those of some other groups, are of great geological importance, distinctly marking, as they do, a new epoch in the history of creation, and which, in our next article, we shall show continues to increase its wonders, and manifest the most extraordinary combination of organic forms.

MATHEMATICS.

CHAPTER XII.

ARITHMETIC OF COMPOUND NUMBERS—PRACTICE—SQUARE AND SOLID MEASURES—DUODECIMALS.

We have no new principle to propose under this head. In the rules already established are comprehended all the operations of arithmetic, whether the numbers to be operated upon be abstract or concrete, whole or fractional. In writing down a concrete or compound quantity, we have seen that it is convenient to abide by an understood though conventional notation, by which the magnitudes of the units forming the expression are known. Thus, in writing down a sum of money, we state how often it contains the unit which we call £1, how often the part that is over contains the unit 1s., how often the remainder contains the unit 1d., and what fraction of 1d. remains; the sum thus expressed may be £7 8s. $5\frac{3}{4}$d. This form of expression is convenient, and its convenience has caused it to be universally adopted in the money transactions of this country. But it is manifest from the principle laid down in our last chapter, that this sum of £7 8s. $5\frac{3}{4}$d. might be written with equal correctness £$7\frac{407}{960}$, which is very nearly represented by £7·424; or we might write instead, 7127 *farthings*.

Bearing therefore in mind the principle, that quantities may be correctly represented by units of different magnitudes, it is clear, that in whatever form a compound number may be written, the expression may be so modified as to allow of its addition, subtraction, multiplication, and division, by the rules prescribed for performing these operations upon fractions. And the operation being completed, it would only remain to convert the result obtained into the common form of expression, that is, into an order of units descending in value from left to right. This is, indeed, often the most convenient and expeditious mode of proceeding, especially in the operations of multiplying and dividing compound numbers. But we can also perform the operations without any alteration of the quantities, and with only a slight modification of the rules already prescribed. We begin as before with

Addition.—The rule for the addition of compound numbers differs from that for whole numbers only in this, that instead of reckoning uniformly by *tens* from left to right, we reckon by tho particular order of units adopted for quantities of the kind expressed. Thus, suppose we are required to find the sum of the two quantities written on the margin, in which *four* units of the class A are equivalent to *one* unit of the class B; *twelve* units of the class B equal *one* unit of the class C; and *twenty* units of the class C equal *one* unit of the class D, which last we may suppose to be of the highest order to which a distinct name is given.

D	C	B	A	
49	8	5	3	} add.
29	13	10	2	
78	21	15	5	= sum.
79	2	4	1	= sum.

Adding the numbers as ranged in the ordinary way, the sum, as first written, is at once found; but, it is clear, that in the column A, no higher number than 3 ought to be found, since 4 is equal to 1 of B; and similarly in column B, we ought not to find any higher number than 11, since 12 of B are equal to 1 of C; and in column C, the highest number must not exceed 19, since 20 of C = 1 of D. Hence, although the first sum as written be correct, it ought, for the sake of symmetry and convenience, to be written as in the second sum-line. This is readily found by carrying successively by 4 in A, by 12 in B, by 20 in C, and finding D as in the addition of whole numbers, taking care to add the carriage figure from column C. The principle of this may be represented to the eye as follows:—

D	C	B	A		D	C	B	A
			5	=	. . . .		1	1
		15 . . .		=	. . . .	1	3	
	21			=	1	1		
78				=	78			
78	21	15	5	=	79	2	4	1

It is obvious that any question of the addition of compound numbers may be treated in precisely the same way. A variation does, indeed, occur in the order of the units, and consequently in the system of carriage; but, knowing the order of the units, that is how many of one denomination make a unit of the nex higher denomination, there exists no more difficulty in finding the sum of a series of compound quantities than there is in finding the sum of a like amount of simple numbers. In the example above, it will be observed, that we took the order of units of sterling money, consequently the question is identical with that upon the margin, except that the farthings are written here as fractions of a penny, and not as before separately.

£49	8	$5\frac{3}{4}$
29	13	$10\frac{1}{2}$
£79	2	$4\frac{1}{4}$

From what has been already stated, the operation may be described as in the following

Rule for the addition of compound quantities.—Write down the given quantities under each other in such a manner that all the units of the same denomination may stand in the same column. Add together the units of the lowest denomination, and divide the sum by the number of that denomination which makes one of the next higher; set down the remainder, if any, under the column to which it belongs, and carry the quotient to the next column. Add this column and divide as before. Proceed in the same manner with all the columns, until arriving at the column of the highest denomination, which is to be added up as in the addition of simple numbers.

Subtraction.—The mode of subtracting one compound quantity from another is like that of adding compound quantities, a simple modification of the general rule for subtraction. The principle is the same; namely, that the difference of two quantities is not altered by adding the same quantity to both. Suppose it required to find the difference of the quantities on the margin when 16 of A = 1 of B; 28 of B = 1 of C; 4 of C = 1 of D, and 20 of D = 1 of E.

	E	D	C	B	A
From	4	8	2	21	13
Take	2	17	0	25	14

Here we observe that three of the numbers in the lower line are greater than those immediately over them in the upper line, and conse-

quently the same artifice which we employ in the subtraction of simple numbers becomes necessary; that is, we must increase the 13 of A in the upper line by 1 of B = 16 of A, and the 25 of B in the lower line by the same quantity; we must in like manner increase the 21 of B in the upper line by 1 of C = 28 of B and the 0 of C in the under line by the same quantity; also the 8 of D by 1 of E = 20 of D and the 2 of E by the same quantity. When these alterations are made, the quantities will stand as upon the margin, and the difference as there shown is easily found.

Modified form.

	E	D	C		A
From	4	28	2	49	29
Take	3	17	1	26	14
Remr.	1	11	1	23	15

This process shows the principle in the clearest possible light; but instead of proceeding in this laborious way in practice, we write down the quantities in the given form, and make the necessary alterations mentally. Thus observing that 14 cannot be taken from 13, we *borrow* 16 (that is, 1 of B) and for readiness subtract the 14 from that number; this leaves 2, which added to 13 gives 15 as the remainder under A. We next *carry* 1 to 25, and observing that 26 cannot be subtracted from 21, we *borrow* 28 (that is, 1 of C), and subtracting 26 from that number, we obtain a remainder of 2, which we add to 21, making 23 as the remainder to be set down under column B. Carrying 1 to 0 of C in the under line, and subtracting, we get 1 as the remainder to be set down in that column. Under D, as we cannot take 17 from 8, we *borrow* 20 (that is, 1 of E), and subtracting 17 from that number, we have 3 to be added to 8, making 11 as the remainder to be set down, and carrying 1 to 2 of E, and subtracting, we get 1 for the remainder to be there set down.

In this example we have to take the order of units from ounces up to tons of avoirdupois weight, and therefore the question is in reality the following:—

From	4 tons	8 cwt.	2 qr.	21 lb.	13 oz.
Take	2 tons	17 cwt.	0 qr.	25 lb.	14 oz.
Remainder	1 ton	11 cwt.	1 qr.	23 lb.	15 oz.

It is evident that the same method may be followed when the quantities are of any other sort; consequently the process may be generally described as in the following

Rule for the subtraction of one compound quantity from another compound quantity.—Write down the quantities under each other as in addition, placing the number to be subtracted, *for convenience*, in the lower line. Begin at the lowest denomination, and subtract successively the quantities in the lower line from those immediately over them, observing that when the number of units to be subtracted is at any time greater than that from which the subtraction is to be made, a number of units of that denomination equal to one unit of the next higher denomination is to be added to the last number to make the subtraction possible. To correct the error introduced by this step, increase the next number to be subtracted by 1 before subtracting. Proceed in this manner with all the denominations to the highest, where the subtraction must always be possible; for if not the question would be absurd.

Multiplication.—The common process in multiplication, it will be recollected, depends upon the principle that, if a quantity be separated into several parts, and each of these parts be multiplied by a number, and the products be added, the result is the same as would arise from multiplying the whole quantity by that number. The only modification of the general rule in its application to the multiplication of compound quantities, is only such as is rendered necessary by the difference between the scale of numbers and the tables of money, weights, and measures.

As an example let it be required to multiply £3 12s. $10\frac{1}{2}$d. by 25. Here the quantity to be multplied is made up of 3 pounds, 12 shillings, 10 pence, and 2 farthings; and

2 farthings × 25 =	50 farthings = $12\frac{1}{2}$d.	or £0	1	$0\frac{1}{2}$
10 pence × 25 =	250 pence = 20s. 10d.	or 1	0	10
12 shillings × 25 =	300 shillings	or 15	0	0
3 pounds × 25 =	75 pounds	or 75	0	0
The sum of these is		£91	1	$10\frac{1}{2}$

and this is the product of £3. 12s. $10\frac{1}{2}$d. by 25.

This process might be written, for convenience, as on the margin.

£3	12	$10\frac{1}{2}$
		25
£91	1	$10\frac{1}{2}$

We might here, as in the preceding instances, have taken a general example, such as that annexed, where 12 of A = 1 of B; 3 of B = 1 of C; $5\frac{1}{2}$ of C = 1 of D; 40 of D = 1 of E; and 8 of E = 1 of F. The calculations in this case will stand as follows:—

F	E	D	C	B	A
4	3	15	2	1	2
					20
88	3	28	3	2	4

			F	E	D	C	B	A
2 of A × 20 =	40 of A	=	0	0	0	1	0	4
1 of B × 20 =	20 of B	=	0	0	1	$\frac{1}{2}$	2	0
2 of C × 20 =	40 of C	=	0	0	7	$1\frac{1}{2}$	0	0
15 of D × 20 =	300 of D	=	0	7	20	0	0	0
3 of E × 20 =	60 of E	=	7	4	0	0	0	0
4 of F × 20 =	80 of F	=	80	0	0	0	0	0
And the sum of these is			88	3	28	3	2	4

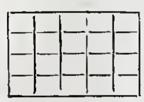
This question, it will be observed, is identical with the following one:—What is the product of 4 miles 3 furlongs 15 poles 2 yards 1 foot 2 inches, multiplied by 20? Ans. 88 miles 3 furlongs 28 poles 3 yards 2 feet 4 inches.

From what has been here shown, we may describe the process as in the following

Rule for the Multiplication of Compound Quantities.—Multiply the units of the lowest denomination by the multiplier, and divide the product by the number of its units required to make one of the next higher denomination; set down the remainder, and carry the quotient. Perform the same operation upon the next higher denomination, adding the carriage number before dividing. Proceed in this manner until arriving at the highest denomination, which is to be multiplied as if it were an abstract number.

It will be found, by referring back to Chapter III. p. 74 of Vol. I., that we have given other rules than that used here, when the multiplier is large, and also when composed of factors. These modified rules afford good exercise for the student, but the general rule is, in the case of compound numbers, invariably the most simple and direct in practice. For this reason we do not consider it necessary to give any examples of the application of the other rules: if this be wanted, any elementary treatise on arithmetic will afford abundance.

It may be necessary here to remind the student that a multiplier is a number which expresses simply the times or parts of a time that a given quantity is to be taken, and can never, therefore, itself be a concrete number. In our arithmetical rules we indeed often speak of multiplying concrete quantities together, as miles by hours, shillings by yards, and in some of the older books we meet with rules for finding the square of a sum of money; but expressions and rules of this kind must be regarded as abbreviations, else they are perfectly absurd. We cannot, for instance, form any notion of 10 miles taken 6 hour-times, of 12 yard-repetitions of 15 shillings, or of £99 19s. $11\frac{3}{4}$d. added £99 19s. $11\frac{3}{4}$d. times; but we readily enough form a conception of 10 miles repeated as many times, as 1 hour must be repeated to make 6 hours, that is 6 *times*, of 15 told down once (1 *time*) for every yard in 12 yards, and also of a stock of money increased at the rate of £99 19s. $11\frac{3}{4}$d. for every £1 in it. We also speak familiarly of multiplying feet by feet, and inches by inches, and of obtaining for product square feet and square inches. Suppose a table 5 feet long and 4 feet broad; to find its superficial content, we are directed by the rule to multiply the length by the breadth, which, taken literally, requires us to make "4 feet-repetition of 5 feet." This is absurd; but suppose the surface of the table is divided into squares in the manner of a chessboard; then, because there are 5 feet along the side, there are 5 squares in the row, and because there are four feet along the end, there are 4 rows. To find the number of squares in the whole, we have simply now to take 5 square feet 4 times, and add them together, which is evidently not multiplying feet by feet, any more than if there were a shilling on each square, it would be multiplying shillings by shillings, to find their number by multiplying the number in a row by the number of rows.



Division.—The division of a compound quantity is performed upon the same principle as the division of abstract numbers;

viz., that if a quantity be divided into any number of parts, and each part be divided by any number, the different quotients, added together, will make up the quotient resulting from the division of the whole quantity by that number. Thus, suppose it required to divide £68 13s. $3\frac{3}{4}$d. by 21. Since 68 divided by 21 gives the quotient 3 and remainder 5, the given quantity is made up of £3 × 21 = £63 and £5 13s. $3\frac{3}{4}$d. The quotient of the first (21 being the divisor) is therefore £3; and it now remains to find the quotient of the second. Since £5 is 100s., £5 13s. $3\frac{3}{4}$d. is 113s. $3\frac{3}{4}$d.; and 113, divided by 21, gives the quotient 5, and remainder 8, showing that 113s. $3\frac{3}{4}$d. is made up of 105s. and 8s. $3\frac{3}{4}$d. The quotient of the first is, therefore, 5s.; and it now remains to find the quotient of the second. Since 8s. is 96d., 8s. $3\frac{3}{4}$d. is $99\frac{3}{4}$d.; and 99, divided by 21, gives a quotient 4, and remainder 15; that is, $99\frac{3}{4}$d. is 84d. and $15\frac{3}{4}$d.: of the first, the quotient is 4d. Again, since 15d. is 60 farthings, $15\frac{3}{4}$d. is 63 farthings; and 63, divided by 21, gives for quotient 3, and no remainder; that is, 63 farthings, divided by 21, gives for quotient 3 farthings, or $\frac{3}{4}$d.

We have thus divided £68 13s. $3\frac{3}{4}$d. into four parts, each divisible by 21; viz., £63, 105s., 84d., and 63 farthings; giving for quotients, £3, 5s., 4d., and $\frac{3}{4}$d.: so that £68 13s. $3\frac{3}{4}$d., being divided into 21 equal parts, the magnitude of each of those parts is £3 5s. $4\frac{3}{4}$d., which is the answer to the question proposed.

This process is usually written, for convenience, as upon the margin. Here we first divide the pounds by the given divisor, and find for quotient £3; then reduce the remaining £5 to shillings, and add the 13s. of the dividend. We now divide as before; and the quotient is 5s., with a remainder of 8s. We reduce this remainder to pence, and add the 3d. of the dividend, making 99d. This we divide as before; and the quotient is 4d., with a remainder of 15d. We finally reduce this to farthings, and add the $\frac{3}{4}$d. of the dividend. The result is 63 farthings; which, divided by 21, gives a quotient of $\frac{3}{4}$d., and no remainder. Had there been here a remainder, we would have simply written it down as the numerator of a fraction, with the divisor as the denominator. The fraction thus formed would have denoted so many parts of a farthing.

```
      £  s. d.    £ s. d.
21 ) 68 13 3¾ ( 3 5 4¾
     63
    ----    +13s.
     5×20=100s.
          ----
           113
           105
          ----    +3d.
            8×12=96d.
                 ----
                  99
                  84
                 ----   +3f.
                 15×4=60f.
                      ----
                       63
                       63
                      ----
                        0
```

From the preceding process we deduce the following rule:—Divide the units of the highest denomination, and convert the remainder into units of the next lower denomination, taking care to add to the result any units of that denomination which may be found in the dividend. Divide this result as before. Continue the process, dividing and reducing the remainders as they arise, till all the parts of the dividend are divided.

In the example from which this rule is deduced, the divisor is an abstract number; and therefore the question is to the following effect:—

If a given quantity A be divided into a given number of equal parts, what is the magnitude of each of those parts? The answer Q must obviously be a quantity of the same kind as the dividend A, and of such a magnitude that, being repeated as many times as the divisor contains units, it will be equal to the dividend; and therefore the work may be proved by multiplying the quotient by the divisor. But the following question may also occur:—How many times is one given quantity B contained in another given quantity A? The answer in this case is obviously an abstract number, by which, if the divisor be multiplied, the product will be equal to the dividend.

For example, let it be required to find how often 2s. $3\frac{1}{2}$d. is contained in £3 1s. $10\frac{1}{2}$d. The readiest way of proceeding with questions of this sort is to reduce the given quantities to the lowest denomination mentioned: in this instance to halfpence. Now 2s. $3\frac{1}{2}$d. = 55 halfpence, and £3 1s. $10\frac{1}{2}$d. = 1485 halfpence; the question is therefore this:—How often does 1485 halfpence contain 55 halfpence? But we know that 1485 halfpence contains 55 halfpence just as often as 1485 contains 55, that is 27 times; and therefore £3 1s. $10\frac{1}{2}$d., which is 1485 halfpence, must contain 2s. $3\frac{1}{2}$d., which is 55 halfpence also 27 times.

From this we have the following rule for dividing one compound quantity by another:—Reduce the divisor and dividend into units of the lowest denomination contained in either, and proceed as if the quantities were simple numbers: the quotient is an abstract number.

As an exercise, the student may solve the following question: If 2 cwt. 15 lbs. of sugar worth 11d. per lb. be mixed with 14 cwt. 3 lbs. worth 5d. per lb., how much is the mixture worth per lb.? Ans., $5\frac{3}{4}$d.$\frac{153}{905}$.

By the preceding rules we are able to add, subtract, multiply, and divide compound quantities without changing their form; but, in performing the last two operations, it is often more convenient, as already observed, to convert the compound quantity into a fractional form, and, after multiplying or dividing by the rules of fractions, to value the fraction which results from the operation. Thus, in multiplying £1. 17s. 6d., for example, by $15\frac{1}{2}$, since £1. 17s. 6d. = £$\frac{450}{240}$, which, reduced to its lowest terms, is £$\frac{15}{8}$, we have, by substituting for the compound quantity its equivalent fraction, the following operation:

$$£\tfrac{15}{8} \times 15\tfrac{1}{2} = £\tfrac{15}{8} \times \tfrac{31}{2} = £\tfrac{465}{16} = £29.\ 1s.\ 3d.$$

Or, using the decimal notation, £1. 17s. 6d. = £1·875, and $15\frac{1}{2}$ = 15·5; therefore,

£1. 17s. 6d. × $15\frac{1}{2}$ = 1·875 × 15·5 = £29·0625 = £29. 1s. 3d.

Again, let it be required to divide £2. 12s. $10\frac{1}{2}$d. by $7\frac{3}{4}$. Since £2. 12s. $10\frac{1}{2}$d. = £$\frac{1269}{480}$ which reduced = £$\frac{423}{160}$, and $7\frac{3}{4}$d. = $\frac{31}{4}$; therefore,

$$£2.\ 12s.\ 10\tfrac{1}{2}d. \div 7\tfrac{3}{4} = £\tfrac{423}{160} \times \tfrac{4}{31} = £\tfrac{1692}{4960} = £0.\ 6s.\ 9\tfrac{3}{4}d.\ \tfrac{15}{31}.$$

Employing the decimal notation, £2. 12s. $10\frac{1}{2}$d. = £2·64375 and $7\frac{3}{4}$d. = 7·75; hence the division to be effected is

$$£2{\cdot}64375 \div 7{\cdot}75 = £\tfrac{2{\cdot}64375}{7{\cdot}75} = £{\cdot}34112 \ldots = £0.\ 6s.\ 9\tfrac{3}{4}d.\ \tfrac{1}{2}$$

very nearly, the remaining decimal called $\frac{1}{2}$ being ·475 ... of $\frac{1}{4}$d.

There is a convenient method of multiplication, which, from the extensive use made of it in business, is called *Practice:* we shall endeavour to explain it by the following example:—

Suppose it is inquired how much 175 tons will cost, at £1 12s. $7\frac{1}{2}$d. a ton? It is plain, that if this sum were multiplied by 175, the product would be the price of the whole; but it is likewise clear, that in purchasing 175 tons at £1 12s. $7\frac{1}{2}$d. per ton, payment may be made by first putting down £1 for each ton, then 10s. for each, then 2s., then 6d., and then $1\frac{1}{2}$d.; for these sums would together make 175 times £1 12s. $7\frac{1}{2}$. The reason of this separation of the price £1 12s. $7\frac{1}{2}$d. into different parts will be understood from the following analysis of the process:—

	£	s.	d.
1. 175 tons at £1 each ton will cost .	£175	0	0
2. Since 10s. is £$\frac{1}{2}$, 175 tons at 10s. each, will cost £$\frac{175}{2}$ that is, ...	87	10	0
3. Since 2s. is $\frac{1}{5}$ of 10s., 175 at 2s. each will cost a fifth part of the same number at 10s. each, that is, $\frac{1}{5}$ of £87 10s., which is, . . .	17	10	0
4. Since 6d. is $\frac{1}{4}$ of 2s., 175 tons at 6d. each, will cost a fourth of what the same number costs at 2s. each, that is, $\frac{1}{4}$ of £17 10s., which is,	4	7	6
5. Since $1\frac{1}{2}$d. is $\frac{1}{4}$ of 6d., 175 tons at $1\frac{1}{2}$d. each, will cost $\frac{1}{4}$ of what the same number costs at 6d. each; that is, $\frac{1}{4}$ of £4 7s. 6d., which is, .	1	1	$10\frac{1}{2}$
The sum of all these quantities is	£285	9	$4\frac{1}{2}$

which is obviously £1 12s. $7\frac{1}{2}$d. × 175.

The whole process may be written down as follows:—

					The price of 175 tons at			
10s. is $\frac{1}{2}$ of £1.	2	£175	0	0		£1	per	ton.
2s. is $\frac{1}{5}$ of 10s.	5	87	10	0		0	10	0
6d. is $\frac{1}{4}$ of 2s.	4	17	10	0		0	2	0
$1\frac{1}{2}$d. is $\frac{1}{4}$ of 6d.	4	4	7	6		0	0	6
		1	1	$10\frac{1}{2}$		0	0	$1\frac{1}{2}$
Sum,		£285	9	$4\frac{1}{2}$		£1	12	$7\frac{1}{2}$

From the preceding example it will be observed, that the

method of proceeding is to divide the price into a number of parts, each of which is a simple fraction (that is, a fraction having 1 for its numerator,) of some preceding part. No rule can be given for determining these parts, but, by a little practice, the student readily discovers what division to adopt in each particular case. When the parts are found, it only remains to find how much the whole quantity would cost if each of these parts were the price, and then to add the results together.

It is hardly necessary to observe, that most processes by this rule admit of more than one order of *aliquot* parts of the price. Thus in the example above we might have taken 10s. as $\frac{1}{2}$ of £1; 2s. 6d. as $\frac{1}{4}$ of 10s.; and $1\frac{1}{2}$d. as $\frac{1}{20}$ of 2s. 6d. This order would have given us one division less, and it may afford a good exercise to work the question by these parts instead of those taken.

The following example illustrates a variety of the rule which frequently occurs:—What is the value of 189 cwt. 3 qrs. 21 lb. at 9s. $10\frac{3}{4}$d. per cwt.

Here the price 9s. $10\frac{3}{4}$d. is made up of 5s., 4s., 10d., $\frac{1}{2}$d., and $\frac{1}{4}$d., of which 5s. is $\frac{1}{4}$ of £1; 4s. is $\frac{1}{5}$ of £1; 10d. is $\frac{1}{6}$ of 5s.; $\frac{1}{2}$d. is $\frac{1}{20}$ of 10d.; and $\frac{1}{4}$ is $\frac{1}{2}$ of $\frac{1}{2}$d.; and therefore leaving out the 3 qrs. 21 lb., the price of 189 cwt. may be found as follows:—

	£189	0	0	Or what 189 cwt. would cost at	£1 per cent.		
5s. is $\frac{1}{4}$ of £1	47	5	0		0	5	0
4s. is $\frac{1}{5}$ of £1	37	16	0		0	4	0
10d. is $\frac{1}{6}$ of 5s.	7	17	6		0	0	10
$\frac{1}{2}$d. is $\frac{1}{20}$ of 10d.	0	7	$10\frac{1}{2}$		0	0	$0\frac{1}{2}$
$\frac{1}{4}$d. is $\frac{1}{2}$ of $\frac{1}{2}$d.	0	3	$11\frac{1}{4}$		0	0	$0\frac{1}{4}$
By addition	£ 93	10	$3\frac{3}{4}$		£0	9	$10\frac{3}{4}$

But to this we must add the price of 3 qrs. 21 lb.; and, it is clear, that this being made up of 2 qr., 1 qr., 14 lb., and 7 lb., the price will be found by taking such parts of 9s. $10\frac{3}{4}$d. that these parts are of 1 cwt.: that is, to find the price of 2 qr. we must take $\frac{1}{2}$ of 9s. $10\frac{3}{4}$d.; to find the price of 1 qr. we must take $\frac{1}{2}$ the price of 2 qr. for 14 lb., $\frac{1}{2}$ the price of 1 qr.; and for 7 lbs. $\frac{1}{2}$ the price of 14 lbs., as in the following scheme:—

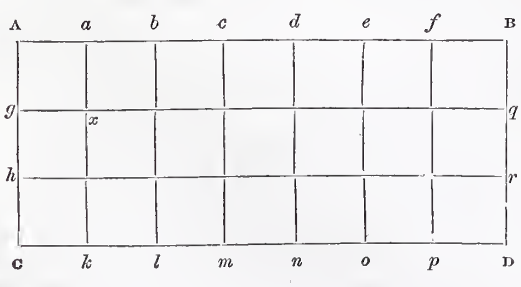
					cwt.	qr.	lb.
	£0	9	$10\frac{3}{4}$	Or price of the quantity	1	0	0
2 qr. is $\frac{1}{2}$ of 1 cwt.	0	4	$11\frac{3}{8}$		0	2	0
1 qr. is $\frac{1}{2}$ of 2 qr.	0	2	$5\frac{11}{16}$		0	1	0
14 lb. is $\frac{1}{2}$ of 1 qr.	0	1	$2\frac{27}{32}$		0	0	14
7 lb. is $\frac{1}{2}$ of 14 lb.	0	0	$7\frac{27}{64}$		0	0	7
By addition	£0	9	$3\frac{21}{64}$		0	3	21

The price of 189 cwt. 3 qr. 21 lb. is therefore £93 10s. $3\frac{3}{4}$d. + £0 9s. $3\frac{21}{64}$d., that is £93 19s. $7\frac{5}{64}$d.

These two examples illustrate all the general methods of proceeding in operations of this kind; and, in order to afford the student a little independent practice, we may propose the following questions:—

1. What is the price of 169 qrs. at £2 1s. $3\frac{1}{4}$d. per qr.? Ans. £348 14s. $9\frac{1}{4}$d.
2. What cost 2627 yards at 7s. $8\frac{1}{2}$d. per yard? Ans. £1012 0s. $9\frac{1}{2}$d.
3. What is the price of 18 cwt. 3 qr. 4 lb. at £3. 18s. 6d. per cwt.? Ans. £73. 14s. $8\frac{1}{4}$d.
4. Value 25 tons 11 cwt. 2 qr. 12 lb. at £4. 8s. 4d. per cwt.? Ans. £2,259. 11s. $11\frac{1}{2}$d.

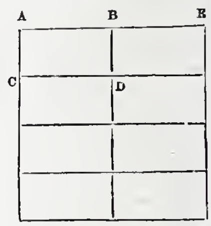
There is a connection between the measures of length and measures of surface, and also of solidity, which is worthy of illustration here. Thus, suppose we have an oblong figure A, B, C, D, as here drawn, and which is called in geometry a



rectangle, with the side A B = 7 inches, and the side A C = 3 inches. Divide A B and C D, which are equal, into 7 inches by the points a, b, c, d, e, f, and k, l, m, n, o, p, and join these points. Similarly divide A C and B D, which are also equal, into 3 inches by the parts g, h, and q, r, and join these points. The figure A, B, C, D, is thereby divided into a number of squares, that is, into figures whose sides are equal, and each equal to 1 inch: thus, A a g x, is a square of 1 inch, since A a = g x = A g = a x. In the whole figure there are three rows of these squares, and seven squares in each row, that is, there are $7 \times 3 = 21$ squares altogether. Each of these squares having each of its sides = 1 inch in length, is what we call a *square inch*. And, by the same reasoning, if one side of the figure had contained 7 *feet* or *yards*, and the other 3 *feet* or *yards*, the surface would have contained 7×3 *square feet* or *square yards*.

In a similar way it might be shown that, did our figure represent simply the surface of a rectangular block (a brick, for example, called in geometry a *parallelopiped*), whose depth was 4 inches, the number of solids (cubes) contained in it, whose four sides were each a square inch, would be $7 \times 3 \times 4 = .84$. These we would call *solid* or *cubic inches*; and were the units of length *feet* or *yards*, the resulting cubes would be *solid feet* or *solid yards*.

From this we can readily see that, a lineal foot being = 12 inches, a square foot must be = 12×12, or 144 square inches; and a cubic foot = $12 \times 12 \times 12$, or 1728 cubic inches. Similarly, a square yard must contain 3×3, or 9 square feet; and a cubic yard $3 \times 3 \times 3$, or 27 cubic feet. A square is, in fact, a rectangle, whose sides are equal; and, therefore, must contain as many square units as there would be squares formed in it by dividing its sides into lineal units of the same name, and joining the points of division. A square of one foot on the side would thus contain 144 squares of 1 inch on the side, the sides of the primary figure being divided into lineal inches. And again, a cube is a solid, containing as many layers of cubic units as there are lineal units in one of its sides. Thus, a cubic foot is composed of 12 layers, each containing 144 cubic inches; that is, 144×12, or 1728 cubic inches altogether.



Again let it be supposed that the figure A B C D, instead of being a whole number of inches, contains some inches and a fraction. For example, let A B = $5\frac{1}{2}$ inches, and A C = $3\frac{1}{4}$ inches. Draw A E twice as long as A B, and A F four times as long as A C, and complete the rectangle A E F G. Then, since A E is twice as long as A B, or twice $5\frac{1}{2}$ inches, it is 11 inches; and since A F is four times as long as A C, or four times $3\frac{1}{4}$ inches, it is 13 inches: therefore the whole rectangle A E F G contains 11×13, or 143 square inches. But the rectangle A E F G contains 8 rectangles, each of the same size and form as A B C D; and therefore A B C D is one-eighth part of A E F G, and contains $\frac{143}{8}$, or $17\frac{7}{8}$ square inches. But $\frac{143}{8}$, or $17\frac{7}{8}$, is made by multiplying $5\frac{1}{2} = \frac{11}{2}$, and $3\frac{1}{4} = \frac{13}{4}$, together.

From these cases, then, it appears that, whether the sides of a rectangle be a whole or fractional number of units, the number of square units in its surface is the product of the number of lineal inches which express its length and breadth. And in like manner it might be shown that, whether the sides of a rectangular parallelopiped be whole or fractional units, the number of cubic units contained in it is truly found by multiplying together the number of the lineal units denoting its length, breadth, and thickness.

If the principle here explained be properly understood, the student will find little difficulty in computing either surfaces or solids; but practice has introduced a modification, much used by artificers in measuring wood, deals, and superficial work, as painting, plastering, and so on. The method referred to is called *Duodecimals*, because the fractional parts diminish constantly by 12 from left to right; so that 12 of any inferior denomination make 1 of the next superior denomination. Thus, suppose it is wanted to find the contents of a surface which is 9 ft. 5 in. long, by 4 ft. 6 in. broad. The length and breadth are

written as upon the margin. We first multiply the 5 by 4, and divide the product 20 by 12, and set down the remainder 8 under the 5, and carry 1. We next multiply the 9 by 4, and, adding the 1 carried to the product, set down the result, 37. We then multiply by the 6, and divide the products, as they arise, by 12; but, in putting down the remainders, we move each a place farther to the right than that of the figure multiplied. Thus, 6′ is the remainder which arises from multiplying the 5 by 6, and dividing the product 30 by 12. Adding together the several products, we obtain a result which, according to custom, ought to be read, 42 ft. 4 in. 6 parts. The true answer is, however, 42 sq. ft. 54 sq. in.; and may be found thus:—

ft.	in.	
9	5	
4	6	
37	8	
4	8	6′
42	4	6′

9 ft. 5 in. $= 9\frac{5}{12}$ ft., or $\frac{113}{12}$ ft.; and 4 ft. 6 in. $= 4\frac{1}{2}$ ft., or $\frac{9}{2}$ ft. Now, $\frac{113}{12} \times \frac{9}{2} = \frac{1017}{24}$; and this, taken as square feet, and reduced, gives 42 sq. ft. 54 sq. in.

To explain this apparent discrepancy, it is only necessary to observe, that the 4 in the preceding answer does not express square inches, but strictly twelfths of a square inch; while the third term, here called parts, strictly denotes square inches. The answer, as found, is therefore $42\frac{4}{12}$ square feet, 6 square inches; but $\frac{4}{12}$ square feet $=$ 48 square inches, and 6 square inches added make 54 square inches as found by the common process. From this, then, it appears that each duodecimal inch is equal to 12 square inches, and must be reckoned as such.

Again, let it be required to find the solid contents of a log of wood $19\frac{1}{2}$ feet long, 18 inches broad, and 15 inches thick. Write down the length, and, below it, the breadth in feet and inches, as on the margin; and having multiplied as in the last example, multiply the result by the thickness: the final result found, in the notation of duodecimals, is 36 feet 6 inches and 9 parts, solid measure. But, by the common process, the answer is 36 c. feet 972 c. inches. The apparent discrepancy is, however, explained as before: the 6 duodecimal solid inches are $\frac{6}{12}$ or $\frac{1}{2}$ of a cubic foot; that is 864 c. inches; and the 9 parts are equivalent to $\frac{9}{12}$ or $\frac{3}{4}$ of a duodecimal solid inch, that is, to 108 c. inches; but 864 c. inches $+$ 108 c. inches $=$ 972 c. inches, as found by the common process. From this, then, it appears, that a duodecimal solid inch is equivalent to 144 c. inches, and a duodecimal part solid measure, to 12 c. inches. The next term, which in this notation we call seconds, would denote cubic inches, and so on.

ft.	in.		
19	6		length.
1	6		breadth.
19	6		
9	9		
29	3		
1	3		thickness.
29	3		
7	3	9′	
36	6	9′	

Notwithstanding this apparent confusion in the results found by the duodecimal process, it has its advantage in facilitating the computation of prices. As an instance, suppose the log of wood, the content of which we calculated in the last example, to be sold at 3s. per cubic foot; the content is 36 feet 6 inches 9 parts, solid duodecimal measure, which, at 1s. per foot, is 36s. $+ \frac{6}{12}$ of 1s., or 6d $+ \frac{9}{12}$ of 1d. or $\frac{3}{4}$d., that is 36s. $6\frac{3}{4}$d.; and this sum multiplied by 3 gives £5 9s. $8\frac{1}{4}$d. as the price of the whole log.

Since the duodecimal scale proceeds by *twelves*, it will readily occur to the student, that when yards are given as a factor of a multiplication to be made in the manner prescribed, they must be previously reduced to feet; the feet in the product, divided by 9, will show the number of square yards.

It may also be observed, in connexion with the duodecimal rule, that when boards, &c., taper, the breadths at the two ends are to be added together, and half the sum taken as the mean breadth. The same mode is followed in finding the mean thickness also of logs when the solid content is to be found. The common rule for calculating the solidity of unsquared or round timber, is, to multiply the square of $\frac{1}{4}$ of the mean circumference, or girt, by the length. When the tree tapers regularly, the girt may be taken at the middle for the mean girt; or the girt of both ends may be taken, and half the sum will be the mean girt. When the tree tapers irregularly, the girt is taken at regular intervals throughout the length: the quotient arising from the division of the sum of all the girts by their number is the mean girt. When the girt of a tree is taken with the bark on, an allowance is made for it by deducting $\frac{1}{10}$ of the whole girt for oak, and less or more for other wood, in proportion to the thickness of the bark.

Example.—Required the solid content of a tree 40 feet 10 inches in length, the girts at four equidistant places, deducting for bark being 5 feet 10 inches, 4 feet 4 inches, 3 feet 1 inch, and 2 feet 3 inches?

Here the sum of the girts is 15 feet 6 inches, which, divided by 4, gives 3 feet $10\frac{1}{2}$ inches, or extended according to the duodecimal scale of notation, 3 feet 10 inches 6 parts, as the mean girt; a fourth of this is 11 in. 7 parts 6 seconds, which being squared, is 11 inches, 3 parts, 1 second, 8 thirds, 3 fourths; and this multiplied into the length, gives the result as on the margin.

Duodecimal operation.

	ft.	in.	pt.					
4)	3	10	6					= mean girt
	0	11	7	6″				$= \frac{1}{4}$ of mag.
	0	11	7	6				
	0	10	7	10	6‴			
			6	9	4	6⁗		
				5	9	9		
	0	11	3	1	8	3		
	40	10						= length.
	37	6	5	7	6	0		
		9	4	7	4	10	6′	
	38	3	10	2	10	10	6′	

This and similar operations may, however, be much simplified. Thus $\frac{1}{4}$ of the mean girt reduced to the fraction of a foot is $\frac{31}{32}$, the square of which is $\frac{961}{1024}$ foot; and the length of the tree also reduced to a fraction is $\frac{245}{6}$ foot. Then $\frac{961}{1024} \times \frac{245}{6} = \frac{235445}{6144}$ which expresses the solid content in feet; but $\frac{235445}{6144}$ c. ft. $=$ 38 ft. 3 in. 10′ 2″ 10‴ 10⁗ 6′′′′′, according to the duodecimal scale as before.

It may be observed, that although the rule exemplified above, is that commonly made use of in measuring round timber, the content found by it is less than the truth by nearly $\frac{1}{4}$ part of the whole; it therefore makes ample allowance for waste in squaring the timber. A better rule when a nearer approximation is wanted, is to multiply $\frac{1}{5}$ of the circumference of the cylindrical body by double its length; the product is true to within 1 in 190; and if greater accuracy still be desired it may be attained thus; multiply the square of the circumference of the cylinder by its length, and from $\frac{1}{11}$ of the product subtract $\frac{1}{8}$ of itself; the remainder is the answer, and differs from the truth by only 1 in 2300. If a still nearer approximation be desired, multiply the square of the circumference by ·0795775 and the product by the length; the result is the solid content of the cylinder true within 1 in ten millions.

The student will find some exercise in solving the following questions:—

1. The length of a log of wood is 17 feet 3 inches; at the greater end the breadth is 36 inches, and the thickness 20 inches; at the less end the breadth is 18 inches, and the thickness 10 inches; required the solidity? *Ans.* $48\frac{1}{3}$ cubic feet.
2. How much timber in a tapering tree 32 feet long, and girt in the middle of every eight feet, the girts being 64, 56, 52, and 46 inches? *Ans.* 41·92 cubic feet.
3. How many yards of carpet, three-quarters of a yard wide, would be required to cover the floor of a room whose sides are 42 ft. 5 in. and 31 ft. 9 in. *Ans.* $199\frac{1}{2}$ yds. and $\frac{5}{9}$ in.
4. What is the difference between 18 *square inches* and 18 *inches square?* *Ans.* 2 sq. feet 18 sq. inches.

It is worthy to be observed, that if a regularly tapering tree be cut exactly in the middle of its length, the two parts will measure by the common rule, more than the whole tree; and if cut where the girt is $\frac{1}{3}$ of the greatest girt, the greater end will measure the most possible. This part may indeed be found to measure more than the whole tree did before it was cut. There is indeed a rule for finding at what point the section must be made to secure this condition. The following is one form of it:—

$$\frac{L}{2(G-g)} \cdot \left\{ \sqrt{(5G^2 - 2Gg - 3g^2)} - (G + 3g) \right\} = \text{the length}$$

in feet which is to be cut off from the smaller end, so that the greater section will measure as much as the whole tree did before it was cut.

In this formula, L is the given length of the tree, and G and g its girts at the greater and less ends.

THEORY AND PRACTICE OF DYEING.

CHAPTER VII.

MORDANTS.

Tin.—This metal has nearly the colour and lustre of silver; it is one of the few metals which were known to man at a very early period of his history, and was extensively used in all countries, both east and west, having any pretensions to civilization. This was probably owing to the ores of the metal being easily reduced to the metallic state, these being in general oxides; so that by merely fusing them with carbonaceous matter, such as coal, which combines with the oxygen, the metal is fused and sinks in the melted state to the bottom of the furnace.

The principal localities for obtaining tin, are Cornwall in England, Bohemia, Mexico, and the East Indies; the former of these has been wrought for many ages, and may almost be said to be the first nucleus of civilization in this country, as it formed the great mart where the civilized and commercial Phœnicians obtained the tin which was so abundantly used by them. The ore is found in Cornwall both in veins traversing the primary rocks, and in small rounded grains in the neighbourhood of these rocks, imbedded in what geologists term the *alluvial deposit.** This gives the purest tin, and is distinguished by the name of *stream* tin. The ore obtained from the veins is generally contaminated with other metals, such as iron, copper, arsenic, and the like, but is partially purified by liquation, that is, by heating the mass to the melting point of tin, which melts out and leaves the others. Several other operations of refining follow this, which need not be detailed; but there are always some little of the impurities remaining in a portion of the tin. That portion which contains these impurities, is termed *block* tin. The pure *grain* tin is heated till it becomes brittle, and is then let fall from a height, which splits it into small bars or prisms, in which state it is found in commerce. These bars in bending, make a peculiar crackling noise, and become heated. These phenomena are probably owing to the separating of its parts, and the sudden fracture caused by bending. Tin is very extensively used in dyeing and printing both cotton and woollen. The introduction of this substance as a mordant may be considered as forming an era in the art of dyeing, and like many other important improvements in this art, it was the result of accident, which is given by Berthollet as follows. "A little while after the cochineal became known in Europe, the scarlet process by means of the solution of tin was discovered. It is stated that about the year 1630, Cornelius Drebbel observed by an accidental mixture, the brilliancy which the solution of tin gave to the infusion of cochineal. He communicated his observations to his son-in-law Kuffelar, who was a dyer at Leyden. He soon improved the process, kept it a secret in his workshop, and brought into vogue the colour which bore his name."

Soon thereafter, a German chemist found out also the process of dyeing scarlet by means of the solution of tin. He brought his secret to London in 1643; it became known to others, and was soon afterwards diffused over Europe, and its applications became more extended, and whenever a new dye drug was introduced into the art, the solution of tin was universally applied, by which means it became a standard mordant for the various dyewoods, such as logwood, Brazil wood, and the like.

The oxides of tin possess a similar property to alumina, in combining with astringent and colouring substances, and forming insoluble compounds. To obtain these oxides in a state applicable to dyeing, it is necessary to dissolve the metal in some acid, which is generally muriatic and nitric acid, either separately or mixed, according to the substance to be dyed, or the colouring matter used. When an acid dissolves a metal, the metal is said to be first oxidized, either at the expense of the water or the acid, and the acid only combines with and dissolves this oxide. Thus, if nitric acid be used, it forms the nitrate of the oxide of tin, and when muriatic acid is used, it is the muriate of the oxide of tin; but with this last, the way of expressing it is conditional; even chemists do not altogether agree upon this point. Muriatic acid is composed of chlorine and hydrogen combined with water; when tin is put into this acid, there is an evolution of hydrogen gas. Whether this hydrogen be from the decomposition of the water or the acid, is not correctly known; if it be from the decomposition of the water, the salt is then a muriate of the oxide of tin; but if it be from the decomposition of the acid, the salt is simply a soluble chloride. This difficulty leads the student astray, as he sometimes finds in chemical works mention made of the chloride of tin, and none of the muriate, which, being most familiar with the term, he is searching for; but for all practical purposes, they are synonymous. The distinction followed by some is, that when the metal is dissolved in the acid, and kept in solution, such as is used by the dyers, it is a muriate; but when crystallized, or brought to a certain temperature, it is a chloride.

The solutions of tin, in the technical language of the dyehouse, are termed *spirits*, with an affix to each mode of preparation, to denote their special application, such as red spirits, yellow spirits, plumb spirits, &c. The preparation of these spirits are matters of much pride amongst dyers, and each has some little peculiarity he keeps to himself, and to the virtue of which he supposes all his success depends. These peculiarities are generally in the proportion of the acids and the tin, and the manner of mixing them. However, as may be supposed, they are not all equally answerable for all purposes to which they are applied; hence the reason that we find one dyer best at reds, another at purples, another at blacks, and another at browns.

The first process in preparing spirits, is to *feather* the tin. This is done by melting it in an iron ladle, and pouring it when in a melted state into a vessel filled with cold water, the hand to be held as high as possible, so that it may pour more in drops. The appearance of the tin in this state is beyond description beautiful. By this process of feathering, a very extended surface of metal is exposed to the acid, which facilitates its solution very much. If red spirits be wanted, that is, a mordant for dyeing red upon cotton by Brazil wood, the general method is to take three measures of muriatic acid, and one of nitric acid, then add the tin by degrees to this mixture. So long as the acids continue to dissolve it, care ought to be taken not to add the metal too rapidly, but bit by bit, adding one piece just as the other is dissolved. We know that this is not generally attended to, as one handful of the metal is put in after another, at certain and too often irregular intervals of time, giving very annoying results. When the metal is put in too rapidly, or too much at once, the action becomes violent, the solution gets heated, the nitric acid is decomposed, ammonia is formed in the solution, and a quantity of peroxidized tin falls to the bottom when the solution cools, as a gelatinous precipitate, creating much loss. When spirits thus prepared are used for a brilliant red upon cotton by Brazil wood, the proper hue is never obtained, the colour being always more or less brownish. The proportion of these acids for preparing the red spirits, are not invariably three to one, the mixture varies from half and half to five to one, depending upon the taste and experience of the dyer. Some also, only dissolve a given quantity of the metal to the pound weight of the mixed acids, varying from one and a half to three ounces to the pound; but according to our experience, the acids in whatever proportions they are mixed, ought to be saturated, at least so far as they will become saturated, observing the precautions described above. We have also found that when much nitric acid is used, the reds are generally deeper in colour and have a very great tendency to turn brown, especially if the goods be dried in heat; but when the muriatic acid prevails, the colour obtained has more of the crimson or rose tint, and is not so liable to brown in drying.

The process of dyeing what is termed *fancy* red upon cotton, is as follows. The cloth being well boiled from all grease or oil, is put into a boiling hot decoction of sumach, made by boiling a half pound of sumach to the gallon of water, and allowing it to steep in this till the solution be cold, or about twelve hours; from this it is put into the spirit bath or solution of tin, at the strength of about 4° Twaddell. It is kept moving in this solution, so that every part will be equal, for about half an hour, or until it assumes a lemon-yellow colour. Wash from this, till the water passing from it does not taste acid. It is then wrought through a decoction of Brazil wood, of the proportion of half a pound of wood to the gallon of water. After being kept moving through this for twenty minutes, the article is lifted out and a little alum in solution added to the dyeing liquor, as *raising*. The

* Signifying the deposite formed by the washing away of the fragments of the primary rocks with water.

article is again wrought in this for five or ten minutes, washed well through cold water and dried. If a rich yellow tint of red is wanted, a little of the decoction of fustic is added to the Brazil wood, before the goods are first put in. Although the solution of tin we have just described, is technically termed *red spirits*, it may with equal propriety be called *purple*, *brown*, *crimson*, nay, in many instances, *drab* spirits, for it is used for all these colours. If we take the goods prepared for red as detailed above, and put them through a decoction of logwood instead of Brazil wood, we have a deep purple; if we use a mixture of logwood and Brazil wood, we get a crimson, a marron, &c., according to the proportion of the mixture; if we use a decoction of quercitron bark, we get a deep yellow, and by working this yellow through a mixture of logwood and Brazil wood, we have brown. Thus, the same mordant is made available to a great variety of colours; and we need hardly mention that by varying the strength of these decoctions, light and dark shades are obtained of the same colour, although when light shades of the same colour are wanted, it is preferable to use weaker mordants.

When very light shades of purples, puces, and lilacs, are wanted, or lavender, violet, peach blossom, and the like, a different process is adopted. The logwood and tho tin solution are mixed in certain proportions, and the goods require no previous mordant. This mixed solution is termed a *plumb tub*, and by some a *French tub*, being first introduced by the French for the dyeing of silk. The *plumb* spirits are simply a protochloride of tin. The general proportions used by dyers are seven measures muriatic acid, and one water, adding two ounces of tin to every pound weight of the mixture; but in this, as in the others, care must be taken not to add the tin too rapidly. It is well known to all who dissolve tin in muriatic acid in quantity, that if much metal be put into the acid at once, towards the end of the operation, parts of the metal seem to dissolve away, while other parts become coated with a white crystalline substance very difficultly soluble, occasioning much annoyance and loss. This is occasioned by one part of the solution becoming denser than another; a galvanic action is induced between those parts of the tin in the weaker portion of the solution, and the parts in the stronger, consequently, depositing the tin from the solution upon the negative end, which is at the bottom, where the liquor is most saturated. This can be prevented by occasionally stirring the solution.

In the preparation of the plumb spirits, it is best to use pure muriatic acid without water, and to add the tin by degrees, and as long as the acid continues to dissolve it; and where it can be obtained without much cost, we would recommend the salt of tin being crystallized. It is sold in this state by many drysalters, but we have often found it in the market very impure.

A *plumb tub* is prepared as follows:—A quantity of *chipped* logwood is put into a boiler or large pot filled with water; this is brought to boil, and kept boiling till the decoction has the density of at least 8° *Twaddell;* this is carefully decanted into a tall vessel, and allowed to stand for a few days to allow a quantity of tary matter and other impurities to settle to the bottom. It is also of importance that the decoction be perfectly cold; for if at all above summer heat a quantity of the logwood will be precipitated on the addition of the tin. The decoction is again decanted into a suitable vessel, generally a large cask or wine-pipe; to this the chloride of tin or spirits is added until the hydrometer rises to 14°. If the chloride of tin has been crystallized, two or three degrees less will suffice and make a better plumb. After standing twenty-four hours it is fit for use. This forms a kind of stock vat, out of which portions are taken, and diluted or used strong as occasion requires; it lasts a long time, as the goods do not seem to extract the colouring matter from the solution as in other dyes, except by long immersion. When a mordant is upon them, they generally assume a colour corresponding to the strength of the solution.

We will have occasion to notice the peculiar compound formed between the tin and logwood in this mode of combining them, when treating of logwood and its combinations; but we cannot help inquiring here upon what theoretical law does the dyeing by the *plumb tub* depend? It is not ordinary precipitation; for this compound is soluble, and is held in solution for years: we have known one kept two and a half years, and used after. The goods have no mordant upon them previous to being immersed, and in a short time they obtain a dye sufficiently permanent to stand all the usual fatigues of fancy colours. That it is a chemical union between the compound constituting the *plumb tub* and the cloth is not tenable; for, as we have already shown in a former paper, this cannot take place but between the atoms of matter, and at the expense of the original properties of the two substances, which combine. Now the cloth remains unchanged in properties except colour, which may be taken off without in the least interfering with the properties of the cloth. Our opinion is, that in this, as in several other cases in dyeing, the cloth exerts a catalytic influence over the compound of tin and logwood; that is a certain power of causing bodies in contact to combine or resolve themselves into other compounds, while the substance exerting the influence is not affected; as, for instance, a piece of platinum put into a mixture of oxygen and hydrogen, will cause these two gases to combine and form water; or a little sulphuric acid put into starch will convert the starch into sugar, without the acid being destroyed. So, in the same way, the cloth being put into this soluble solution of tin and logwood, may, by inducing a very slight transformation, convert it into the insoluble compound of tin and logwood; and, like other dyes, fills up the hollow fibres of the cloth, producing dark or light shades accordingly.

The *plumb tub* gives white goods the various shades, from a French white to a deep plumb, by dyeing the cloth first light blue, and then immersing it in this preparation. Various shades of lilacs, puces, &c., are obtained by immersing the goods for some time in sumach, and then passing them through the plumb liquor. Various shades of peach blossoms are got in the same way. Thus, by a little manipulation, a great variety of shades and colours are produced by one costly preparation.

Yellow Spirits.—These are prepared in the same manner as the red spirits, only substituting sulphuric acid for nitric acid. This method of preparing the solution of tin was first recommended by Dr Banrcroft as a cheaper method of preparing scarlet spirits, but it was never much used for this purpose, but it was used for a long time for dyeing a deep yellow upon cotton with a decoction of quercitron bark; but the introduction of the bichromate of potash as a dyeing agent has almost entirely superseded every other method of dyeing yellow, as it combines within itself every qualification necessary to give it precedency, namely, beauty, durability, and cheapness.

Barwood Red Spirits.—Take six measures muriatic acid and one nitric acid, add tin by degrees until white bubbles begin to rise to the surface; allow this to stand for twelve hours before using. This is the instruction generally given by practical barwood red dyers for the preparation of their spirits; but this colour being rather difficult to dye, except by much experience, owing to many peculiar properties of the barwood, we will therefore postpone our remarks upon this interesting branch till we are considering the character and properties of the Brazil woods.

Many other methods of dissolving the tin are practised by woollen and silk dyers, such as the following:—Take six pounds nitric acid and one water, dissolve in this one pound of sal ammoniac, to this add ten ounces of tin. The proportions of sal ammoniac and tin are points upon which practical dyers differ. Some use a little common salt as well as sal ammoniac, but the resulting compound of tin is the same as in common red spirits. Sal ammoniac is composed of muriatic acid and ammonia; the nitric acid takes the ammonia, and the muriatic acid is set free and combines with the tin, forming what is termed permuriate of tin. The protosalts of tin dissolved in potash, are extensively used in calico-printing, both as a mordant and a deoxidizing agent—a property which it possesses to a high degree; and, did its price not forbid, might be used instead of protosulphate of iron (copperas) in the common blue vat. Tartrate of tin is also used in many of the operations of calico-printing; but, as the writer is not experienced in the manipulations of the printwork, he must avoid any special reference to that department.

Iron.—We have had occasion to notice the protosulphate of iron, and some of its peculiar properties and combinations, when treating of the blue vat: we will confine ourselves here to the properties of the metal as a mordant.

In the article referred to, the reader will find two oxides of iron described, namely, the protoxide and peroxide; he will also find that both of these oxides combine with acids to form salts, but that the protoxide and protosalts are readily converted into the peroxide and persalts. Both of the salts are used as mordants, but the protosalts are the best for vegetable substances.

It is therefore a matter of much consequence to preserve the iron in this state of oxidation until it be immersed into the dye-bath; this is effected in many instances by astringent substances. For example, in our detailed process of dyeing black, the goods are steeped in sumach, then put through lime water; this turns the sumach on the cloth green, and converts some of its constituents into a state well fitted to combine with oxygen, which it will take from the atmosphere if exposed to it, thereby losing its green colour and resuming the colour it had when taken from the sumach. When the cloth is a deep green it will combine rapidly with the protosalts of iron, such as copperas, and give a black colour; but if a persalt of iron be used, the resulting colour is a grey slate. The former becomes darker as it stands, the latter greyer; but the theory of these actions and reactions we must pass for the present. When we take the goods rendered black by the protosalt, and put them through lime water, they are converted into a rich brown from the peroxidizing of the iron; but, if allowed to stand exposed to the air for a short time, they assume their black colour again. If the goods are put into the logwood when they are of this brown colour, the black is seldom good. They ought always to be allowed to assume the black hue before being immersed in the logwood bath. For this reason we have always preferred washing them from the copperas rather than putting them through lime water.

The general iron mordant for wood dyes is the acetate of iron (iron liquor), or what is most commonly used now, the pyrolignite of iron. The acetate of iron may be prepared by mixing together acetate of lead and protosulphate of iron. The sulphate of lead is formed and falls to the bottom; the acetate of iron remains in solution, but it is generally prepared by throwing pieces of iron into the acid, which dissolves it. The pyrolignito of iron is in general preferable. It is prepared by allowing iron to steep in pyroligneous acid (impure acetic acid) for several weeks. As this acid contains a quantity of pyrogeneous oils and other impurities, it preserves the iron for a longer time in the state of a protoxide than almost any other solvent available in the arts; hence the decided preference given to this by practical men. We shall often have occasion to refer to this subject, as it is one which is too much neglected, and which produces many serious evils. It may, however, be in the meantime observed that pyrolignite of iron, used instead of copperas in dyeing black, gives a preferable shade of colour.

Persalts of iron are mostly used for dyeing Prussian blue. Many attempts have been made to dye black by merely impregnating the goods with peroxide of iron, and immersing them into a decoction of logwood, to save all the routine of steeping, washing, and dipping of the ordinary black, but it has never succeeded. A very good black is obtainable when newly dyed, but very soon changes into brown.

The principal persalt of iron used is the nitrate. This is made by putting clean iron into nitric acid, by which it is very quickly dissolved. The iron ought to be added as long as the acid continues to dissolve it; but cautiously, otherwise the action will be so violent as to cause it to boil over. While engaged in this process care ought to be taken not to breathe any of the fumes which come off, as they are very destructive of health. The reaction which takes place between the acid and the iron may be thus expressed:—The nitric acid is composed of five atoms oxygen, and one nitrogen; every fourth atom of nitric acid in the solution is decomposed to give oxygen to the iron, so that the remaining three atoms of nitric acid may combine with it; better shown in the following diagram:—

One atom nitric composed of { Nitrogen, Oxygen, Oxygen, } → Nitric oxide.
{ Oxygen, Oxygen, Oxygen, }
3 Iron
3 Nitric acid → 3 Nitrate of iron.

The nitric oxide is the gas which flies off; but its attraction for oxygen is so great, that, the moment it is liberated from the solution, it combines with oxygen from the air, and is converted into nitrous acid gas, the well known red fumes which always fly off when metals are dissolved in this acid.

The nitrate of iron alone dyes a buff or nankeen, which is probably the easiest dyed colour that we have, as it is only necessary to put a little of the nitrate of iron into water, and immerse the goods. The particular use of this salt is for Prussian blue. The goods are first dyed buff by this salt of iron, then thoroughly washed, and put into a very dilute solution of ferroprussiate of potash,—made acid by a few drops of sulphuric acid; they are washed from this in clean water, to which a little alum has been added. We have known many attempts made to substitute copperas for nitrate of iron for dyeing Prussian blue, but need hardly say they were unsuccessful. A very little knowledge of the nature of these salts would have told the experimenters that protosalts of iron give only a greyish colour with yellow prussiate of potash; but, if red prussiate of potash was used, copperas would be a better mordant than nitrate of iron, as it gives a dark blue with the protosalts, and only a greenish grey with the persalts of iron.

We have now briefly noticed the three principal mordants, namely, alumina, tin, and iron. There are others which, strictly speaking, may be ranked as mordants, such as lead, copper, zinc, manganese, &c.; but these having a more limited application, we will prefer noticing them as we detail the method of dyeing the several colours for which they are used. We shall in the next paper take up the various dyewoods, after which we shall enter more extensively into the mineral substances, a field which is yet spacious, offering an ample harvest for the practical man who may combine a little science with his practice.

METHOD OF RENDERING LINEN, COTTON, AND WOOLLEN FABRICS WATERPROOF.

By Mr. John Hart.

Conceiving that a description of a ready mode of waterproofing fabrics, especially those to be used as wearing apparel, may not only be generally interesting but extensively useful, we think it may not be out of place to present our readers with such a plain and practical explanation of the process as may render it sufficiently well understood to be practised either domestically, or upon the great scale. We have, in consequence, been favoured with the following excellent exposition of the principle; and although Mr. Hart does not enter upon the details of the particular modes of waterproofing adopted by individual manufacturers, he leaves little, if anything, unexplained, that is essentially necessary to be known, in order to practise the process with certainty of success.

To guard against misconception, it must be observed, that the kind of waterproofing referred to is totally of a different nature from that introduced and patented by the late Mr MacIntosh. By that process the fabric is rendered equally impervious, both to air and water: it is besides costly. But by the process of waterproofing to be described, any linen, cotton, or woollen fabric, even of very open texture, may be rendered, if not altogether impervious to water, of such a nature as not to allow the water to penetrate into the body of the cloth. This condition is beautifully exemplified by the hair of the otter, and the feathers of water-fowl; the water adheres to the surface fibres, but does not penetrate to those beneath the surface, except when considerable friction or great pressure is used. The waterproofed cloth, also, like the natural waterproof coverings of these aquatic tribes, allows air freely to penetrate among its fibres; and the perspiration from the body, when the fabric is made into wearing apparel, escapes through it with the same facility as before it was waterproofed, as it still retains all the openness of texture that it previously possessed.

This property is given to the cloth by coating the fibres of which it is composed with a varnish or solution, which, on exposure to the action of the air, acquires properties in every way analogous to leather dressed with alum. By this leather-varnish, as we may term it, the fibres are completely encased and protected from the action of the water. Water, indeed, readily adheres to the varnished surfaces of those fibres with which it comes in contact, but does not slide or travel along them, and, consequently, does not penetrate beneath those composing the surface of the fabric. This principle is illustrated by dropping a little water upon a clean leather glove: it will be found not to spread over the surface; and, if dropped between the fingers of the glove, they may be held from one-tenth to one-eighth of an inch asunder without the water falling through.

This quality is conferred upon cloth by simply passing it through a hot solution of weak glue and alum—putting it in fact through paper-maker's size, and in precisely the same manner as paper-makers do in sizing writing paper—a process, by the way, the whole object of which is to render blotting-paper waterproof, so that the ink when applied by the pen, shall adhere to the fibres of the surface, and not sink or diffuse itself as it does, when applied to blotting or unsized paper. However, as the mode of sizing of paper is by many as little understood as the waterproofing of cloth, we shall endeavour briefly to describe it in order to place the general principle involved in as clear a light as possible.

To save labour, in making paper for printing upon, and also wrapping papers, the size is generally added when the materials are in the state of pulp; but writing and drawing papers are always sized after being formed into sheets. In the operation of sizing, the workman takes up a number of sheets, and putting a straw between every two to keep them apart, he dips the bunch gently into the hot size. After holding them in the solution until they are completely saturated, he withdraws them and lays them aside to drain. He proceeds in the same manner with bunch after bunch. After draining some time, the sheets are collected together and put under a screw-press, to squeeze out all the superfluous size. When the operation of squeezing has been completed, the sheets are taken from the press, separated, and hung upon cords in a shed having free access of air. Here then, after a few days' exposure, the gelatine passes under the conjoined influence of the alum with which it was associated in the size and the oxygen of the atmosphere, into the state of leather.

The glue or size used in this process must be of the purest quality. When cold it is weak and tremulous—about the consistency of calves-foot jelly. When required for use a portion of it is put upon the fire—in a brass pan, to prevent coloration; and, when it has become pretty hot, a lump of alum is added, and the whole kept stirring until the taste of the alum predominates, and is distinctly perceived. The lump of alum is then taken out, and the size is ready for use. Sometimes a little soap, rosin, or turpentine is added, according to the fancy of the papermaker; but none of these are essential to the waterproofing property of the size.

When any of this size gets by accident upon the clothes of the workmen, they observe that water, a shower of rain for instance, only wets the surface, and does not sink into the sized portions of the cloth: these still preserve their colour, while the other portions become darkened by the water sinking into the substance of the cloth. To render the whole of the dress waterproof, and of a uniform appearance when exposed to wet, no expedient could more naturally suggest itself than to apply the size to the whole surface of the dress; and hence this mode of waterproofing clothes in all probability originated with the papermakers themselves, and was, in some measure, a matter of necessity rather than of choice.

Now, to waterproof any sort of cloth or made garments, all that is necessary is to make a very weak solution of glue or size, and, while hot, to add a piece of alum in the same manner as for sizing paper; at the same time to add a little soap also, or rather soapsuds to it, and then, while it is hot, to brush over the surface of the clothes with this solution. However, if the dress is new, and of fine cloth, it is safer to apply the solution only to the inside, to avoid shading and stains; and the outside of the article ought afterwards to be passed over with a brush or sponge dipped in cold water to smooth down the pile of the cloth. But, for Fustians, Tweeds, or any other cloth that will not become shaded, or on which shadings are of no consequence, it is better to apply the size with a brush to the outside at once; but a sponge ought never to be used with this size, otherwise it will be rendered useless, as it will no longer imbibe water afterwards, if it has once become dry.

The preferable mode, however, is to waterproof the cloth while in the web. In this state it can be dipped into the solution, and afterwards wrung out; or, what would be better still, passed through a pair of squeezing rollers, and the pile of the cloth afterwards laid smooth with the brush and cold water. The use of the soap is to take away the hard feel that the size, when applied alone would impart to the cloth, and which would also render it more difficult for the tailor to sew. The process on the large scale is, besides, an exceedingly cheap one; there is little labour required to pass a web of cloth through squeezing rollers, and not only is the sizing material in itself cheap, but only a very small portion of it is essential to the waterproofing of a large surface of cloth, as the greater part of it is expressed by the squeezing rollers, only as much being left in the cloth as to cause it to feel damp. Exposure to the air, in the same way as sized paper is dried, completes the process of waterproofing.

The evil effects of wet clothes, and the ease with which these effects can be obviated, appear to us to offer a tempting inducement to the introduction of waterproofing as an essential part in the manufacture of fabrics intended for wearing apparel.

Cloths at least, which are manufactured for the use of those portions of the working classes whose avocations necessarily expose them to the inclemency of the weather, should invariably be thus prepared; indeed, while government is assuming to itself an anxious care of the general health, especially of those portions of the community who cannot avoid exposure to inclement weather on all occasions, it would do well to include within its sanatory regulations the qualities of the cloth which are manufactured for garments. It is hardly a question, whether improper clothing be prejudicial to health; nor is it a question, notwithstanding the popularity of the cold-water cure, whether clothing soaked with rain water be proper clothing to protect the body from cold and its thousand concomitant evils. But the same material, which may be inefficient to protect the wearer when unsized from the slightest sprinkling of rain, may be rendered dry, comfortable, and warm clothing, by an additional amount of labour expended upon its manufacture, and at an expense so small as scarcely to be felt in the price of a whole suit of clothes. The object, indeed, is one which it would be for the benefit of the community that it were placed under the surveillance of the excise; and, in order to give full efficacy to a sanatory regulation of so much importance, I would not regret to see a law enacted, which should declare all unsized cloths, of certain kinds and qualities, offered for sale, after a definite period, seizable.*

Even cotton goods for female dresses ought to be finished in the same manner, as the waterproofing does not leave the fabric by any ordinary washing; for unless the cloth be washed with water at the very point of boiling, it will still be found waterproof when dried. And it may also be observed that sized cloth is not so easily soiled as cloth which is not sized.

In families, the process of sizing might be substituted with advantage for starching in dressing linens. To travellers and those occasionally exposed to rain, this would be of very material advantage, as the linen—the collar of a shirt for instance—although it be wetted on the surface, will not become flaccid and fall down like wet linen. Neither will it lose its colour as the rain does not sink into it; and the wet is again speedily evaporated from its surface when the rain ceases. Or the collar may be wiped dry with a pocket handkerchief, and no further inconvenience is felt.

We have now in our possession some specimens of the different kinds of fabrics waterproofed in the manner described, and we observe, on immersing any of them in water, that the external layer of fibres only becomes wetted, and that the water, on account of its own molecular attraction, and the tenacity with which it adheres to those fibres with which it is actually brought into contact, does not spread or penetrate into the cloth. It would seem, indeed, as if the texture of the fabrics were filled with air, which the fibres of the material had the power of keeping fixed, and into which the water cannot penetrate. The specimens of waterproofing to which we refer, are a portion of black woollen cloth, which is perfectly impervious to water, though quite pervious to air; a shirt collar, dressed by the sizing process, which has lain in water for the last twelve hours, and is as stiff and dry within as when immersed; a piece of fine muslin, in a cress of which an ounce of water was poured at the same time that the collar was immersed, and not a drop has passed through; a piece of bobinett, which allowed some water to pass through its meshes when poured upon it, but none since; and a cotton handkerchief, in which a bundle of water has been tied up for the same time, and which lies upon our table at this moment, as dry on the outside as if it contained an equal amount of flour.

* This depends upon the question, whether the community has the right to insist upon its members taking due care of their own health, comfort, and wellbeing. Abstractly, we think the community would be justified in making and enforcing domestic, as well as public sanatory regulations, but we much doubt the expediency of any direct interference with the *liberties* of the subject on these delicate points, especially where the injury to the community is one of an indirect nature.—Ed.

It may be worth while to refer to the process which has long been known and practised by fishermen, to render the substance of their nets, boat-sails, and occasionally their canvas trousers, waterproof. This process is called *barking*, and consists in simply boiling the article in water, along with a few waste fish and some oak-bark. This renders the article, after being dried, quite impervious to water; it, in fact, renders it waterproof. The principle is, moreover, the same as that which we have above described. The fish furnish the requisite gelatine, which the tannin of the oak-bark converts into a solution of tanned leather—just as the alum in the paper size converts the gelatine present with it into a solution of alum-leather. Both of these solutions, when dried under exposure to the action of the air, become perfectly insoluble in cold water, and therefore form a complete envelope to the fibres. To this coating the water adheres, and therefore does not readily travel along the surface, as may be observed by looking attentively at the action of water upon the surface of a piece of bobinett which has been so treated; and perhaps the reader may have observed the same fact exemplified in the drops of water hanging among the fibres of fishing-nets, when newly hung up to dry, at the same time that these fibres are themselves comparatively dry and rigid to the feel, although just taken out of the water, in which they have been immersed for hours.

FLAX,

AND THE PROCESSES OF ITS MANUFACTURE.

CHAPTER I.

IMPORTANCE OF THE FLAX CULTURE—AMOUNT IMPORTED—ARGUMENTS FOR ITS HOME GROWTH—RIPPLING—STEEPING—WATT'S NEW PROCESS—BREAKING AND SCUTCHING.

Much attention has lately been directed to the growth and manufacture of flax, and the subject is at present peculiarly interesting, both to the agriculturist and the manufacturer. Perhaps there is no article in general use, which more strikingly illustrates the intimate connection subsisting between the respective operations of these two classes, and their mutual dependence on each other. The agriculturist manufactures the flax in the first stages of the process: he raises the raw material, passes it through some preliminary operations, and then it is handed to the manufacturer to be carried through the subsequent stages, until it is ultimately wrought up into a beautiful textile fabric for the use of man.

The manufacture of flax has lately received an impulse from several important inventions and applications of machinery, by which the requisite operations have been greatly facilitated and improved in effect; and this again, combining with other causes, has led to a great agricultural movement on the subject, with a view to extend the cultivation of flax in this country, and even to give it a permanent footing on our soil, in the regular rotation of crops. At present, the whole quantity raised in the British Isles, is understood to be not more than 150,000 acres, of which about 130,000 are due to Ireland alone; while the demand for our manufactures is sufficient to absorb the produce of from half-a-million to 700,000 acres. To meet this extensive demand, the raw commodity is chiefly imported at present from Belgium, Holland, and Russia; but various experiments are now in progress in several parts of this island, with a view to its growth in sufficient quantities to meet the home consumption, and even, if possible, to render it an article of export. The advantage to the home-grower consists in the absence of any expenses for freight, and in the highly improved machinery and processes for its preparation, which have been placed at his command by the inventions of Schenck, Watt, Plummer, Chevalier Claussen, and others.

The returns of dressed fibre (flax and hemp) imported into this country during the ten years, from 1841 to 1851, give an average of about 70,000 tons per annum, which, at £30 per ton, amounts to upwards of £2,000,000 sterling. To this we must add about £1,500,000, the value of 650,000 quarters of linseed, used for seed and for crushing purposes; and about £500,000, the value of 70,000 tons of oil-cake, which we annually import, in addition to that made at home, for feeding purposes. Thus we are contributing the sum of no less than £4,000,000 annually to the farmers of other countries, for an article of produce especially our own, and which, on all hands, is acknowledged to be, under fair management, a paying crop. It might be presumed, from the immense importation, that the soil of Great Britain was not adapted to the cultivation of this plant, and yet it is now generally admitted, that no part of the world is better fitted for producing the crop in abundance and of good quality. It is true, that the flax of Holland and Belgium sells at £150, or sometimes even £180, per ton, while the finest samples grown in Norfolk and Bedford have never realized beyond £100; but occasional samples of Irish growth have brought as high prices as the best Belgium flax, and the fact of its general inferiority to the latter can only be attributed to want of proper care in its cultivation. Russian flax, the export of which amounts to 40,000 or 50,000 tons per annum, does not sell at a higher price than £48 per ton.

The objection generally urged against the cultivation of flax in this country is, that it is an exhaustive crop, and that it consequently injures the soil. This, however, is found to be not the case under proper management. It is true, that the flax abstracts from the soil a larger amount of nitrogen than many other crops, but an examination of the stem shows that those portions of it which are required for the purpose of manufacture, are derived almost exclusively from the atmosphere. It has been found, upon analysis, that 100 lbs. of the fibre do not contain, on an average, more than 2 lbs. of mineral matter; and the restoration of the steep-water, and of the woody portions of the plant, with the husks of the seed, to the soil, is found to completely renovate the land, making it as well fitted to produce any crop as before. These valuable substances have generally been thrown away, and hence the alleged exhaustive nature of the crop. An extensive cultivator of flax in Ireland states, as the result of many years' experience, that, "when grown in its regular rotation, flax is far from being exhaustive; that it tends greatly to improve the soil, and the character of the other crops in the rotation." He adds, "It is, above all, most valuable for laying down land after wheat or oats, as the process of pulling the flax, after loosening the earth around the roots, improves greatly the quality of the grass crops." This testimony is confirmed by that of Lord Monteagle, who states that the cultivation of flax has actually improved some poor land on his estate, and that no meadow yielded such excellent grass as that on which the flax had been grown. It is also, when properly managed, and when it can be carried to a proper market, highly remunerative to the grower. From particulars given of the flax crops of fifty-one farmers in the county of Down, as published in a report of the Royal Irish Flax Society, it appears that the average profit, *from the fibre only*, was £7. 1s. 4½d. per acre. In none of these cases was the seed saved, otherwise the profits might have been considerably increased. A grower who saved both seed and fibre has shown, by his published statement, that he realized a profit of not less than £6 per acre over what the wheat crop would have yielded.

It is remarkable that, in the face of these facts, we should still be almost entirely dependent on foreign countries for our supply of flax. Our climate is peculiarly adapted to its growth, and our spring is even more favourable to this plant than that of Belgium, where the long and severe droughts which prevail at that season, cause the crop to fail every three or four years. It is true, that the moisture of our summers, and especially the heavy rains with which we are usually visited about the end of July or beginning of August, when pulling-time approaches, are frequently injurious to the crop, and in this respect the Belgian cultivators have a decided advantage; but still, both our climate and soil are admirably suited to its culture—and even in the Highlands of Scotland, there are thousands of acres at present lying waste, on which there can be little doubt that flax might be grown with a very satisfactory remuneration. It is grown, at the present day, in all the northern countries of Europe, as well as in Sicily, Italy, and on the coasts of the Mediterranean. America produces a considerable quantity, principally valued for its seed, from which the oil is expressed, and then it is moulded into cakes,

which are used to a large extent for fattening cattle. Of late, the cultivation of flax has much increased in Egypt, where, amid the rich alluvial oils of the Nile, it is found to attain to a better quality of fibre than in India and other eastern countries. But still, even the Egyptian flax fetches an inferior price in the market, compared with that which is grown in temperate climates; for although, undoubtedly, a native of the countries bordering on the tropics, the plant is found to be improved in delicacy and elasticity of fibre when transported to more northern latitudes. The seed, it is true, deteriorates in quality; but to produce the best fibre, a slow, steady growth is required, and this is attainable only in temperate climates, alike removed from the intense heat of the tropics, and the short but hot summers which characterize the countries approaching the extreme northern limits of the temperate zone.

Flax (*linum*) is an annual plant of fragile appearance, bearing a purplish-blue flower, which springs from a slender fibrous stem, about eighteen inches high. It has narrow alternate leaves, and the flowers are followed by globular seed-vessels,

Fig. 1.

Flax Plant.

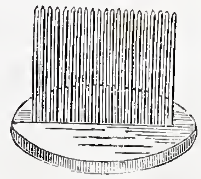
containing slippery brown seed, flattened and elongated. The stalks are hollow pipes, surrounded by a fibrous rind, the filaments of which are the valuable portion of the plant for manufacturing purposes, and furnish the material for cambric, linen, and other similar fabrics. When the seeds are expressed, they yield the linseed oil so extensively used in the arts, and are afterwards, as already stated, compressed and moulded into cakes for fattening cattle.

Linen, or linen yarn, is the name of the manufactured article, derived from the Latin name of the plant. The raw material, flax, is the fibrous portion of the plant, between the exterior skin or bark, and the interior wood or boon. It constitutes, in modern times, a staple manufacture in almost all European countries. Its fibres yield thread or yarn for every kind of manufacture, from cambric, however delicate, to shirting, bed and table linen, sailcloths, tarpaulings, &c. The beautiful kind called cambric was first manufactured at Cambray, a city of France; and to the same material we are indebted for the celebrated lace of Brussels, Valenciennes, Lisle, and Mechlin. It will therefore be seen that its uses and applications are most extensive; and the recent discoveries of Chevalier Claussen, which we shall describe in a subsequent part of this article, promise to render it a cheap and admirable substitute for cotton and woollen fabrics, and thereby to increase its manufacture and consumption to a truly amazing extent.

RIPPLING.

The former practice was to gather the flax straw when the seeds were not perfectly ripe; and this practice, generally speaking, is still continued, where the object is chiefly to secure the fibre, and not to obtain the benefit of the oil-cake and the oil. By Chevalier Claussen's process, however, the flax is pulled when the seeds are perfectly ripened, in which state the fibre is found to be equally good, and the other products of the plant are turned to the best account. The flax, as we have just observed, is *pulled*, and not cut. It is pulled up by the roots, and the first process to which it is subjected is *rippling*. The object of this operation is to separate the bolls, or seed heads, from the stalks; and this is performed by drawing the latter briskly through an iron comb (fig. 2), having smooth round teeth, which stand about twelve or eighteen inches out of the wood, and are placed so close together that the seeds cannot pass through them. They are generally made about half an inch square, a quarter of an inch asunder at the bottom, and tapering slightly to the tops, which are sharpened to receive the flax when thrown upon them. The piece of wood or of metal into which the teeth are screwed, is bolted down to a bench or long stool, on which two persons sit astride, facing each other, and draw alternately their handful of flax through the ripple, allowing the seed-bolls to fall into a winnow cloth, spread below to receive them. This operation is usually performed in the field, and two men with one rippling-comb will take the seed off more than half an acre per day. The seed-bolls, when stripped off, are dried, and stored away in bags in an airy place, to preserve them from moisture, which would cause them rapidly to heat. To avoid this, it is necessary that they should be well dried.

Fig. 2.



Rippling Comb.

There are several processes for converting the raw material —the flax straw—into the dressed fibre suitable for the spinner; this appears, indeed, to be the department in the flax industry that has received most attention, as upon this point the success of the subsequent operations hinges. It will perhaps render a description of these processes more readily understood, if we briefly give the composition of the material from which the fibre is to be obtained. When a portion of flax straw is examined, it is found to consist of three distinct parts: the centre is occupied by a substance composed of cellular tissue, and in appearance like wood; round this is a tubular sheath, composed of bundles of long and tough fibres, cohering firmly together, the whole being cemented together by some azotised compound, and enveloped in a thin and delicate covering or skin. If a piece of the dried straw be rubbed between the fingers, the skin is immediately removed, and the fibrous portions are readily detached from the woody centre. These fibrous portions being composed of bundles of very delicate filaments, may be split up into almost any degree of fineness, according to the process adopted. Now, these various processes differ very much in their mode of separating the fibre from the other portions of the plant. They may be classed under two heads—the "mechanical," or dry preparation, and the "chemical," or wet preparation, by which latter the plant itself is disintegrated, either by the action of fermentation, which destroys, or of some solvent, which abstracts, the cementing matter by which its various parts were held together. Of the first, but little need be said, as, except for rough goods, not requiring to be bleached—as rick covers, canvas, &c., it could not at present be advantageously used. However, as it costs as much to steep bad straw as good, and the expenses, in some cases, exceed the value of the produce,

it would appear desirable that the dry process should be adopted where the raw material is of very inferior quality, and also in places where there are no opportunities of steeping and scutching the flax by the ordinary method. Several modes have at different times been devised for effecting this mechanical separation. In 1815, the Irish Linen Board expended £6,000 in an endeavour to introduce into Ireland a machine for the purpose, invented by Mr. Lee, a model of which may still be seen in the White Linen Hall at Belfast; and, more recently, those by Donlan, Davy, and others, have been brought before the public. Even in the event of a successful result in the separation, the goods manufactured from the fibre would appear liable to be injured by moisture, or any other condition that would act upon the azotised substance, which would still remain, enveloping and cementing the fibres together.

The second, the chemical process, is carried out in several different ways—the principal one, the common "cold-steep," either in pits or streams; the improved method due to Schenck, in which a regulated fermentation, at a high temperature, is maintained in vats, by means of steam-pipes; the process reintroduced by Claussen, in which the straw is treated with a hot alkaline solution; and, lastly, *the new* and greatly improved method invented by Watt, in which steam is the only agent employed, thus avoiding the noxious influence of fermentation, and the expense, and often injurious effects, of the alkaline solution. In the first two, the body of the straw is disintegrated, the cementing substance being destroyed by putrefactive fermentation; in the two latter, this substance is merely removed by solution in the different menstrua. We shall describe in detail these different methods, all of which have the same object in view.

STEEPING.

In ordinary practice, the first process to which the straw is subjected is that of cold *steeping*, or retting. The ripplers lay down their handfuls on the left side, where they are tied up in sheaves, and ought to be carried immediately to the steep-pool. The object of the steeping is to separate the fibrous or filamentous portion of the stalk from the woody part, termed the *boon;* and in order to this, the gum, or resinous sap, which binds the parts together, must be dissolved. Instead of steeping the plant in water, the same effect is produced in some places by mere exposure on the grass to the combined influence of air, dew, and rain; and this method is termed *dew-retting*, or *rotting*, in opposition to the former, which is termed *water-retting*. The water method is that usually adopted, being accomplished in a much shorter time. Sometimes the flax is immersed in running streams; and a gentle current flowing over it, sufficient to carry off the scum which gathers on the surface of the water, is always desirable. But most of the rivers in this country are too rapid for this purpose, and therefore it is usually steeped in pools, or in vats or artificial pits filled with water. The steeping is most perfect when these are in communication with a stream or river, so as to produce a slight current on the surface. In Belgium, the river Lys is filled with flax for miles, and the gentle current of that river undoubtedly contributes to the very superior quality of the Belgian article. Much also depends on the nature or quality of the water in which the flax is steeped; hard or spring water is unsuitable, and water impregnated with iron, or other metallic solutions, discolours and deteriorates the fibre. The best water is that which is free from impurities, or all foreign ingredients, and which has flowed for some distance exposed to the action of the air.

The sheaves of flax should be packed as loosely as possible in the steep-pool, resting on their butt-ends, with only one layer in the pool, so as to allow the water to flow round them freely. They are left to steep from ten to fourteen days, according to the nature or temperature of the water. The immersion must be continued until the gum-resin, which binds the fibres together, is completely loosened, but it must be stopped before the putrefactive fermentation has proceeded to any extent. Some skill and attention are required in removing the flax from the water at the proper time. If the rotting or decomposition has proceeded too far, not only is the woody matter destroyed, but the fibrous portion, or the flax, is materially injured; on the other hand, if taken too soon, the wood is with difficulty removed. When steeped to the desired extent, which is ascertained by occasionally breaking a few stalks of average fineness, and examining whether the fibre can be easily pulled off from the woody part without breaking, the sheaves or bundles are removed from the pools, and set up on their butt-ends to drain for twenty-four hours, after which they are spread out to dry in the open air. Short and close pasture, forming a smooth carpet, is the best for this purpose; and the flax should be evenly spread in rows, so that, by means of a lath, it may be easily turned over, that each side may be equally exposed, otherwise a difference in quality and colour will be found. Too little attention is generally given in this country to these important details, on which the market value of the crops so much depends. The flax remains on the grass for a few days, or a week, according to the state of the weather, and is then lifted, tied up in sheaves, and packed under cover, or stacked and thatched in the rick-yard, where it may be kept for years, rather improving than deteriorating for three or four seasons after the process of steeping.

This method of cold steeping in pits or pools is that which is most general in Ireland, each farmer superintending the produce of his own land. The straw, too frequently with its seed, is carelessly placed in the pit, which is usually about four feet deep, and of an oblong shape, care being taken that the whole mass is covered by the water. Even under the most favourable circumstances, this is a loose and uncertain practice; much time is occupied, the fermentation is irregular, and the produce is less in quantity and inferior in quality to that obtained by Schenck's process. This was introduced into Ireland in 1848, when its advantages were so obvious that the Flax Society at once recommended it to the notice of those proprietors who were in a position to carry it into operation in their respective districts.

The method introduced by Mr. Schenck of New York, consists essentially in raising the temperature of the water in which the flax is steeped, to such a point as to produce the acetous fermentation in a few hours. For this purpose a number of large circular vats are provided, and these are furnished with steam-pipes, connected with a boiler. The flax is placed in these vats, in which it is held down by strong cross bars of wood, to prevent it from floating on the surface when the swelling of the mass, produced by the fermentation, commences. Water is then run into the vats, and steam is admitted to circulate through the pipe at the bottom, till the water is raised to about 90° Fahr., at which temperature it is maintained. Fermentation is soon established, producing a rapid decomposition of the resinous or gummy matter which binds the fibres together, and causes them to adhere to the wood. The decomposition is completed in about sixty hours, and the flax is then taken out of the vats to be dried, either in the open air, or by artificial means. In favourable weather, it is dried in the open air, by tying it up in tufts or handfuls, suspended in rows, tier above tier, in an open framing, which is covered over at the top: in damp weather, it is loosely piled in a drying chamber, into which a current of heated air is admitted. This process possesses the important advantage, that it is not accompanied by the exudation of any noxious effluvium, and does not, like the ordinary method, impart to the water of the district those deleterious qualities which, in flax-steeping pools or rivers, are found to be poisonous to fish, and must, therefore, be more or less insalubrious.

The first rettery on Mr. Schenck's principle was established in Mayo, in 1848. At the present time there are about twenty at work in the different provinces. In principle it is the same as the *cold steep*, but by using heated water the fermenting process is accelerated, and can be controlled according to the quality of the straw or the produce desired. Much time is saved; the three or four weeks of the old process are reduced to three or four days; the fibre is more equal throughout, and is improved in quantity and in quality. In some comparative experiments, conducted by the Flax Society, into the merits of the two methods of steeping, it resulted that, in *increased yield*,

Schenck's gave an advantage of about 20 per cent.; that, in *quality*, two samples of Schenck's spun respectively to 70 and 101 lea yarn, while two samples of the same flax, cold steeped, only spun to 60 and 96 lea yarn; and that, in market value, the former gave a return of £10. 12s. the acre, against £9. 8s., the value of the latter. This process, then, was a great advance upon the old. Time was saved, a better article was produced, and a system of divided manufacture was introduced which relieved the grower from a duty inconsistent with his vocation, and assured him of a quicker and more certain return for his produce. The principle of fermentation, however, is in itself faulty, as it is quite impossible so to control it as to insure a perfectly equal action throughout the mass; besides which, the products of decomposition are noxious to those employed, and offensive to the neighbourhood. The plan reintroduced, by Claussen, of boiling the straw in an alkaline solution, is free from these objections, and effect the same end by dissolving, instead of decomposing, the cementing substance. The time required, too, is again much lessened, being only from 12 to 24 hours. Experience has not yet pronounced upon the value of this method; indeed, with the exception of one or two works upon a small scale connected with the patent, it has made very little progress, notwithstanding the extraordinary assistance it has had from the public press.

Another process has been patented by Mr. Bower of Leeds, the principle of which is compression, for the purpose of expressing the glutinous matter from the fibre. Mr. Bower has found, that in flax, steeped or retted by the ordinary method, a portion of the glutinous matter still adheres to the fibre, rendering it less fitted for the subsequent process of scutching; and therefore, after steeping for a few days in warm or cold water, he passes the flax between rollers, for the purpose of expressing the glutinous matter from the interior of the plant. The steeping and rolling are repeated, and the flax is then dried and treated in the ordinary way. For flax of the finer descriptions, a solution of caustic ammonia, or any of the neutral salts, is used, in the proportion of 1 lb. of the salt to 150 lbs. of rain-water; with which, as a steep, at any temperature from 90° to 120°, the operation is completed in about thirty hours. By Chevalier Claussen's process, the flax is boiled for four hours in caustic soda, or steeped in a cold solution of it for twenty-four hours. It is afterwards washed in water, containing one per cent. of sulphuric acid, and then in pure water. The hot-water method, with or without an admixture of one of the alkaline salts, is now being pretty generally adopted, as an undoubted improvement in respect of accelerating the process, and improving the quality of the flax fibre.

We now come to the last new process, that just patented by Watt, in which steam is the only agent employed, and which, from its extreme simplicity and effectiveness, appears likely to supersede all the others. The whole arrangements are inexpensive, and occupy but little space. The straw is placed in a steam-tight box, or chamber, of any size or shape, the top being formed by an iron tank containing cold water, and the lower end having a perforated false bottom fixed at about 12 inches from the other. Steam, at a low pressure, is blown into the box, and, passing up through the straw, comes in contact with the iron top, by which it is condensed; then, trickling down through the mass, it passes through the false bottom, carrying with it the extractive matter which it has dissolved out of the straw. This is continued for from 8 to 12 hours. The straw is then removed, and is passed through four sets of rollers, which squeeze out about 80 per cent. of the water, and, at the same time, crush the stems, breaking up the central woody substance, and materially assisting its subsequent separation from the flax fibre. From these rollers it is carried to the drying-house, which is heated by steam-pipes from the boiler, and thence to the scutching-frames, where the operation is performed more rapidly and efficiently than when the flax is prepared by steeping, owing to the thoroughly crushed state in which it comes from the rollers.

The flax is then ready for market, having passed through the whole process of conversion in a very short space of time. This important improvement upon the other processes is now being carried out by Messrs. Leadbetter of Belfast, who have erected the necessary buildings for carrying it out upon an extensive scale. From the work that has already been done, it is shown that the entire operation may be completed in 24 hours; that, on the average, 1 ton of straw will produce $2\frac{1}{2}$ cwt. of dressed flax; and that the condensed liquor from the steaming-chest contains matter of a nutritious nature, having, according to analysis, a feeding-value equal to distillery wash. This may be advantageously used by being poured, while hot, over the broken capsules, or seed bolls, which contain in themselves much nutritious matter, and in this state are readily eaten by cattle or pigs. The flax produced has already been sold at high prices, and has been pronounced by spinners to be of apparently unexceptionable quality.

A preliminary meeting in reference to this invention has been held by the Flax Society, and a large committee, composed of its members and of others interested in the trade, has been appointed for the purpose of instituting "a careful and extensive series of experiments, with a view to compare it, both in a practical and financial point of view, with the modes of hot and cold steeping generally practised." At present it would appear to possess the following advantages:—

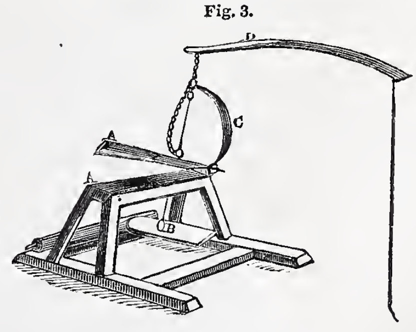
1. Great saving of time. 2. Economy of fibre, owing to the facilities with which it is separated from the "shove," or woody centre, in the scutch-mill, thereby producing little waste in scutching tow, which latter is only worth from 6s. to 10s. per cwt., while the long fibre from which it is torn away is worth from 50s. to 100s. per cwt. 3. Avoidance of any nuisance. Instead of the offensive products of the steep, an inodorous liquid is obtained, which may at once be consumed advantageously for feeding purposes. 4. The encouragement it will offer for the extension of flax cultivation throughout the country, by affording an opportunity to those who desire it of organizing, at a small outlay, an establishment which will always insure a ready market for the produce of the district.

Much good has already been done in this respect by the introduction into several districts, of retteries on Schenck's system, those in operation purchasing directly from the farmer, and steeping upwards of 30,000 tons in the course of the year. The new process, however, being able to complete the operation in a quarter of the time required by the other, would, of course, be able to turn out four times as much work in a given time; and, as the arrangements would be less expensive in outlay, it offers an advantageous opportunity to all friends of Irish industry who wish to encourage the home cultivation of flax, and to retain in the country a portion, at least, of that large sum which is annually expended in purchasing the necessary supplies from foreign countries.

BREAKING AND SCUTCHING.

The next operation is the "breaking," with a view to the entire removal of the woody portion of the plant. In Russia, Holland, and Belgium, and even in some parts of Ireland, a simple hand-brake is used for this purpose. The workman stands before a bench, on which are placed three longitudinal bars; and corresponding to the intervals between these, are two bars affixed to the lower side of a lever, attached by a fulcrum to the bench, so that, when brought down, the bars of the lever rest in the grooves or openings between the bars on

Fig. 3.

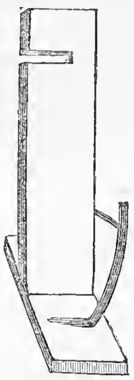


The Brake.

the bench. The flax being placed on the under bars, and turned over and over by the hand, is crushed and broken by repeated strokes from the lever.

The *brake* is sometimes worked by the foot, as in fig. 3, where A A are the two rows of iron grooves meeting on the flax, and B is a flat moveable piece of wood, attached by a chain or string to an iron spring, C, fixed at the extremity of the bench. The pressure of the foot on the board, B, causes the descent of the upper set of bars, by which the woody part of the flax is bruised without cutting or injuring the fibre. Instead of the spring, C, a spring-pole, D, may be used, and will give more power. By bruising in this machine, the woody part of the stem is prepared to separate freely from the flax in the operation of scutching. This operation, also, in the countries above-mentioned, is chiefly performed by hand. The flax is introduced into the groove, B, of the wooden stand, A (fig. 4), and is beaten with a broad flat blade of wood, so as to strike away the bits of woody matter. The operation is assisted by a buff-leather belt, stretched between the stand and an upright stake, C, on which the blade falls after striking the flax, and by its rebound from the leather the labour is materially diminished. Any bits of wood which remain are cleared away with a broad blunt knife, the flax being scraped across the worker's leg, which is covered with a piece of leather to resist the injury from friction. From eight to fourteen pounds of clean flax can be turned out by an active scutcher in a day.

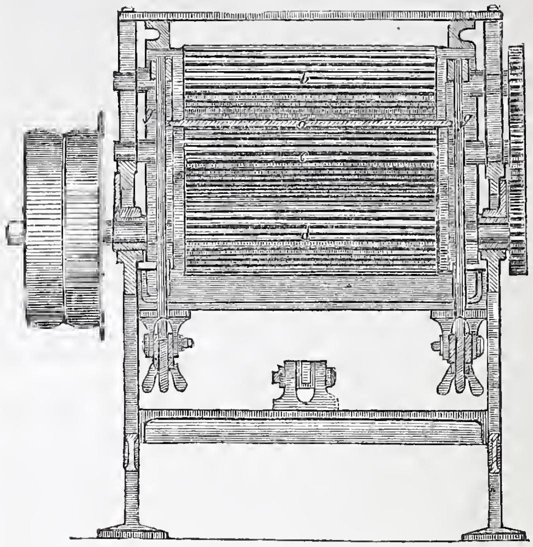
Fig. 4.



These very simple and primitive machines afford a sufficient illustration of the rationale of the processes of breaking and scutching, which are, however, more expeditiously accomplished by means of power machinery. In the rolling or crushing mill, the retted and dried flax is passed by hand between a series of fluted rollers, the fluting or parallel projections of which correspond to the bars of the hand-brake, described above. The rollers bruise and crack the boon, already loosened by the retting, and spread or partially separate the long fibres. On emerging from this machine, the flax is gathered up by boys, and handed to others, who submit it by handfuls to the action of rotating knives, corresponding to the wooden scutch-blade above-mentioned. These knives, in the ordinary machine, are attached to the face of vertical wheels, several of which are mounted on the same shaft, at two or three feet apart; and an attendant is stationed at every wheel, who submits the flax to the action of the knives, by holding it over a bar fixed near them, and allowing the rotating knives to strike the flax in the direction of its length. When one half-length of the flax is thus treated, the other end is turned round and subjected to the same operation. By this means the boon is considerably cleared away; but to clean the flax more thoroughly, it is again passed through a similar operation before another set of wheels, on which the knives are so placed as to act with a more searching effect. Being now reduced to a strick of comparatively fine fibre, the flax is ready for sale, and in this state it enters the flax-mill, to be operated on by the heckling-machine, the object of which is the removal of the *tow*, or short staple, before undergoing the operation of spinning.

The most recent improvements in breaking and scutching machines, are those patented by Robert Plummer, Esq., of Newcastle-upon-Tyne, and exhibited in Class VI., No. 74, of the Great Exhibition. A front elevation of his flax-breaking machine is shown in fig. 5; and fig. 6 is a side elevation of the same, without the framework. This machine is so contrived, that the flutes in one roller do not quite touch those on another, and hence the flax straw, in passing between them, is less damaged, while at the same time it is more completely crushed and prepared than in any other. The rollers, five in number, are placed in two vertical series, one before the other, the front one of two rollers, the back one of three. In fig. 5, the letters *b*, *c*, and *d*, are placed upon the grooved metal rollers, to which the flax is presented, as shown in fig. 6, being laid upon the table, *a a*, from which it is taken up and passed between the rollers, *b c*. The circular bent plate, *g g*, causes the straw, partially broken by these rollers, to pass between the rollers, *c* and *d*, from which it is delivered to the front rollers, and

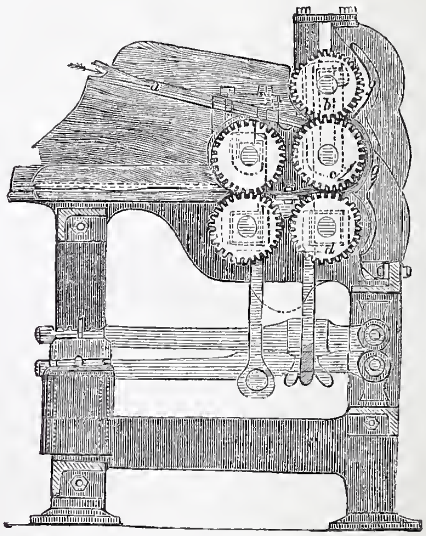
Fig. 5.



Flax-breaking Machine—(back view.)

finally emerges from the machine by the table, *b*. The direction in which the rollers revolve is indicated by the arrows. The flax, however, may be delivered to the machine by the table *b*, and pass in a contrary direction, emerging by *a a*. If not properly broken by passing once through the rollers, the flax may be inserted a second time, and the operation repeated.

Fig. 6.



Flax-breaking Machine—(side view.)

The principal novelties of this arrangement claimed by the inventor are, that the straw passes three times through between a less number of fluted rollers than usual, and that, by means of the guide-plate, *g g*, the flax is bent round the middle roller, so as to be more easily broken in the rest of its course, and thus more effectually operated upon than by any other machine now in use.

In next chapter we shall describe the further processes of scutching, heckling, &c.

PHOTOGRAPHY, OR PHOTOGENIC DRAWING, CALOTYPE, DAGUERREOTYPE, &c.

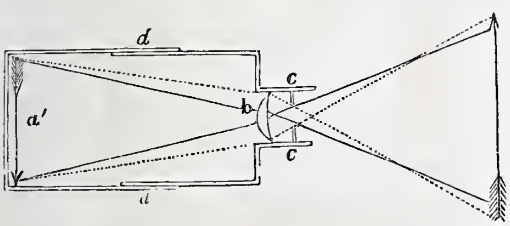
CHAPTER III.

THE PHOTOGRAPHIC CAMERA—MR. TALBOT'S RESIGNATION OF HIS PATENT RIGHTS.

Having given in our last chapter the processes for copying engravings, and various natural objects, without using the camera obscura, we now proceed to indicate those processes in which the camera forms an essential part of the simple apparatus employed. It does so in taking sun-drawings both by the calotype and daguerreotype processes, and those in which the surface prepared for receiving the impression is that of a smooth glass plate. Before proceeding, therefore, to describe the details of these methods, we must begin by explaining the *rationale* of the camera, and pointing out those forms of the instrument that seem to be most suitable for photographic purposes.

The *camera obscura*, or *darkened chamber*, was invented by Friar Bacon in the thirteenth century, but has been attributed by some to Baptista Porta of Padua, who published, at Antwerp, in 1560, the first detailed account of it. It is an optical apparatus for the representation of objects under the same angle which they subtend to the unassisted eye, and which are exhibited on a table, a sheet of paper, or other flat surface, in their proper colour and shape. The principles on which its operation depends have already been explained in this work, in the chapter on "Refraction of Light by Lenses," (vol. i., p. 289.) The image produced by it may be imperfectly exhibited by simply darkening a room, and boring a small hole in one of the window shutters. If a piece of paper be held at a small distance from the hole, the figures of external objects will be seen delineated upon it, invested with their natural colours and shading, but in an inverted position; and by covering the hole with a small lens, the image is rendered much more vivid and distinct, from the condensation of the rays by the spherical glass. The same effect will be produced, if we substitute a darkened box for the darkened room; and such a box, with a lens inserted in a small aperture at one end, and a mirror placed within at such an angle as to throw the image upward on a piece of ground glass placed on the top of the box, constitutes the ordinary form of the camera used by artists for sketching from natural objects. In that employed for photographic purposes, no mirror is used; and the simplest form of the apparatus is shown in fig. 1, where *b* is a lens inserted in a circular opening at one end of the box, *d d*, and the image of the arrow, *a*, is shown at *a'*, where it is received upon a sheet of paper, or other plane surface, placed in the focus of the lens, near the back of the box.

Fig. 1.

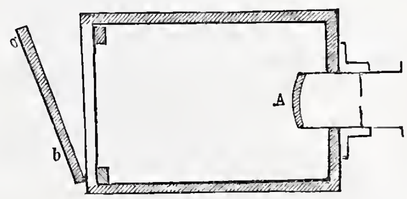


"For the practice of photography," says Mr. Hunt, "with such success as approaches the perfection of the art, an instrument of the utmost refinement is necessary; but the learner may content himself with a very simple and inexpensive form of apparatus. Many of my earliest, and these were by no means my worst experiments, were made with a camera constructed from a cigar-box; a hole being pierced in one end of it, and fitted with a lens, the photographic paper being pinned upon a stiff piece of card-board the size of the box, and placed in the focus of the lens. It is necessary that the box be painted on the inside with a mixture of lamp-black and stiff size, to prevent the reflection of the dispersed light. The diagram, fig. 2, gives this arrangement: *a* being the lens through which the image falls upon the paper fixed on the moveable board at *d*, this being necessarily moveable, since according to the distance of the object from *a*, so will be the focal distance from the lens producing the best image."

Fig. 2.

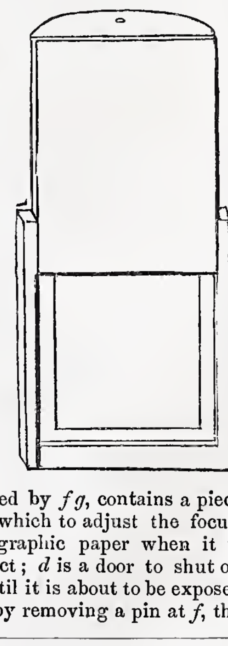
Instead of the board being moveable, the box is usually constructed with a sliding brass tube, in which the lens is fitted, and by which it can be so adjusted, according to its focal length, as to throw the image on a piece of ground glass placed at the back of the box. Fig. 3 is a section of the instrument in this simple form. A is a meniscus lens, having the radii of its curves in the proportion of two to one (see vol. i., p. 291), inserted at the inner end of a sliding brass tube, in which there is also a diaphragm, or stop, placed at a short distance in front of the lens; at the back of the camera slides a frame containing a piece of ground glass, on which the image may be seen from behind, and the proper focus ascertained by removing the back, *b*, of the box. There is also at the back a case, fitted with a glass front, as in fig 4, in which the prepared paper is placed, and a shutter by which it is protected from the light till introduced into the camera, and even till the very moment when the image is to be thrown upon it.

Fig. 3.



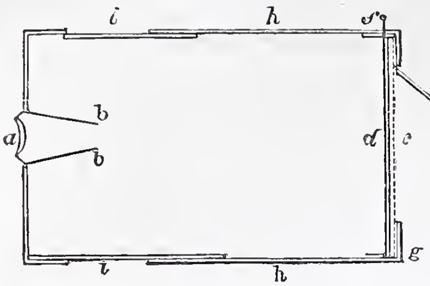
Another convenient and very economical form of the photographic camera is shown in fig. 5. The common instruments of this form consist essentially of two boxes, *i i'* and *h h'*, the former sliding into the latter. The part, *i i'*, in which the lens, *a*, is fixed, may be made the outer box, and in that case the prepared paper is placed in the inner end of the part, *h h'*, and the image is observed through a small hole at the back. But the diagram shows an arrangement which, although somewhat more complex, is found to be very convenient for general use. It consists of three parts, the two extreme portions, *f g* and *i i'*, sliding into the outer case or frame, *h h'*. The third division, represented by *f g*, contains a piece of ground glass, *c*, at the back, by which to adjust the focus, and also for receiving the photographic paper when it is desired to take a copy of any object; *d* is a door to shut off the light from the paper or plate, until it is about to be exposed to the luminous influence, when, by removing a pin at *f*, the

Fig. 4.



door is made to fall inwards; and *e* is another door at the back, through which the image formed on the opaque glass may be examined. In the instrument here represented, the aper-

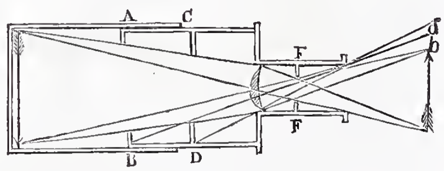
Fig. 5.



ture of the lens itself is made large; but the pencil of rays admitted is limited by a diaphragm at *b*, between the lens and the plane of representation, instead of being placed, as in fig. 3, between the lens and the object. It is fixed at a distance of about one-tenth of the focal length from the lens.

The use of the diaphragm, whether placed before or behind the lens, is to protect the picture from all external light, except that which proceeds from the objects to be copied. Fig. 6 is a

Fig. 6.



section of a form of the instrument suggested by Mr. Cundell, in which there are two diaphragms within the camera, and one in the brass tube in front of the lens, for the purpose of more effectually excluding the superfluous light. It will be observed, that by the diaphragm, or circular "stop," E F, the rays from the barb of the arrow are excluded from the upper, and received only upon the lower half of the lens, at which they fall at a comparatively high and *equal* angle of incidence. By this means the focus is not only sharpened, but thrown to a greater distance at the extremities; and the picture, instead of being formed in a curve, as we shall explain immediately, is formed more exactly in the plane of the surface placed to receive it. The diaphragms, A B and C D, receive and intercept the rays transmitted from surrounding objects, as *d* or *b*.

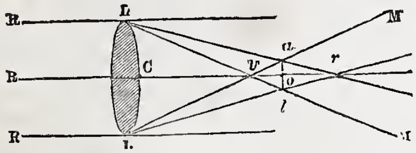
The common double convex lens may be used, but the meniscus form, convex on one side and concave on the other, is preferable. The double convex lens converges the rays that pass through it to the same distance from every part of its inner surface, so that the image, to be formed exactly in the focus, ought to be received on a concave surface, every point of which would be equally distant from the inner convex surface of the lens. By this arrangement, the image, if received on a flat plane, must be, to a certain extent, a distorted representation. To remedy this, and to render the instrument capable of being used for sketching on a plane surface, Dr. Wollaston proposed to make it *periscopic*, by having the lens formed with such curves, that the marginal rays, in converging to the focus, are rendered longer than the central ones. The meniscus shape, having the concave side next the object, and the radii of the surfaces as 1 to 2, is that which must be used for this purpose in instruments in which perfection is aimed at; and with this form Dr. Wollaston states, that an aperture of 4 inches can be employed with a lens of 22 inches focal distance.

These dimensions may be used in sketching distant objects, from which the rays received are nearly parallel, but they are too large for the majority of photographic purposes, and more especially for taking photographic portraits. On this subject an interesting and highly important communication was read by Sir David Brewster at the last meeting of the Royal British Association, in August, 1852, of which the following is an abstract:—

"The object was to show that the photographic portraits taken with cameras with large object-glasses, or large mirrors, must necessarily be distorted and hideous, as, in fact, it is notorious they are; and that hence all persons engaged in this new and most important art should receive with gratitude any scientific discovery which promised to correct so serious a defect—a defect attributed by some to the imperfection of the lenses employed; by others to the unsteadiness of the sitter who is having his portrait taken; by others, again, to the constraint of the features and limbs under which he submits to the operation; but it is by all admitted and deplored. If we consider that the pupil of the human eye is only about 2-10ths of an inch in diameter, it is obvious that the images formed by the eye of those solid objects placed in front of it, and by which we are accustomed to see them, to judge of them, and to recognise them, cannot embrace any of the rays of light which come from those parts of the object that lie in such positions towards the sides, top, bottom, or hinder parts, as cannot pass in straight lines to an aperture of the size of the pupil—in fact, unless it agree almost exactly with the exact perspective form of the object, the pupil being the point of sight. If, then, an object be placed before a lens, the part of the lens towards its centre of the size of the pupil is capable of forming a correct image of that object, consisting of rays coming from precisely the same parts of it as an eye would receive were its pupil in the same position. But all the parts of the lens or mirror of the same size, which lie around and at a distance from this portion of it, would receive rays coming from parts of the solid object which the true eye could not receive, and which must therefore form as many unnatural images as there were such parts; and the photographic picture which embraces and confounds into one hideous mass all these, any one of which by itself would be correct, must, in the very nature of things, give a most confused and unpleasing representation of the object. Sir David illustrated and proved these assertions by a diagram of a lens with a simple solid form, a cylinder topped by a cone behind, placed in front of the lens, pointing out the parts which alone could be embraced in a correct perspective view of it, and what parts of the large lens or mirror would, moreover, receive and transmit rays from the object to be jumbled in the photographic picture, with that which would alone give a correct idea of the object as seen. He showed, from the now familiar illustration afforded by the binocular stereoscope, how very dissimilar were the pictures of the same object received by small lenses, placed as near as the two pupils of the human eye—images so distinct that a child could readily distinguish them; and yet multitudes of such images were all received and jumbled together in those photographic pictures where lenses or mirrors of that or larger —say three or four inches—aperture were used. 'The photographer, therefore,' said Sir David Brewster, 'who has a genuine interest in the perfection of his art, will, by accelerating the photographic processes with the aid of more sensitive materials, be able to make use of lenses of very small aperture, and thus place his art in a higher position than that which it has yet attained. The photographer, on the contrary, whose interests bribe him to forswear even the truths of science, will continue to deform the youth and beauty that may in ignorance repair to his studio, adding scowls and wrinkles to the noble forms of manhood, and giving to a fresh and vigorous age the aspects of departing or departed life.' He then produced an exact diagram of photographic images of a simple object, produced by Mr. Buckle of Peterborough, whose talbotypes—or calotypes—obtained a council-medal at the Great Exhibition. The acting diameter of the lens was 3½ inches; and by using it with all covered, except a central space of 2-10ths of an inch diameter, and then along with this space exposing circular spaces of the same size towards the outer circumference of the aperture, the effect of the combination of the marginal pictures was most distinctly exhibited and demonstrated, by halves extending round the true image, and the sharp cross lines ruled on the object, and shown in the image with the small lens, but all confused in that with the surrounding apertures."

The students of photography are much indebted to Sir David Brewster for this elucidation of a point of the highest importance to the perfection of the art. Allusion is made in these

Fig. 7.



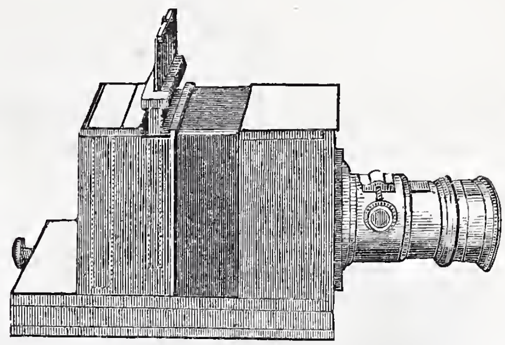
observations to mirrors, or concave reflectors, which are sometimes employed instead of lenses to produce the picture; and this form of the camera was patented by Mr. Beard. The lens is preferable in many respects; but the concave reflector has this important advantage, that it does not, like a refracting medium, separate the rays of light into different colours. This objection to the lens will be understood by the remarks on "Coloured Refraction" (vol. i., p. 321); but it may be better illustrated, with special reference to the use of the camera for photographic purposes, by the diagram, fig. 7, in which we shall suppose R R R to be parallel rays of light falling on the double convex lens, L L. The reader is aware, that in passing through the lens the different colours of the solar ray are unequally refracted, the red being least and the violet most refrangible. If, therefore, the point, *v*, be the focus or point of convergence of the violet rays, the red rays will converge to a point, *r*, farther removed from the lens. In this case, the distance, *v r*, constitutes what is termed the chromatic aberration, and the circle, of which the diameter is *a l*, at the point of mean refraction, is called the circle of least aberration. This is the point at which the image on a piece of paper or ground glass is rendered most distinct. If the image is received on a screen placed at any point between C and *o*, so as to cut the cone, L *a l* L, the luminous circle on the screen will evidently be surrounded by a red border, because it is produced by a section of the cone of light, of which the external rays, L *a r*, L *l r*, are red; but if the image be received at a point beyond *o*, it will be surrounded by a violet border, the external rays being in that case *a* M and *l* M, which are merely the violet rays continued beyond the point of convergence. The clearest image, therefore, is formed, as we have stated, at *a l*; and this is the point at which the ground glass will exhibit the best representation. But the violet rays are those in which the chemical or actinic influence is most powerful; and therefore, in taking photographic pictures, the prepared paper or plate must be pushed a little nearer the lens than the point which is shown by the ground glass to give the best visual focus. To ascertain the best point for producing a sharp photographic picture, the student should make a few trials, by pushing the lens a little nearer to the paper, or the paper nearer to the lens, than the distance of the visual focus, C *o*, as indicated by the ground glass, and then marking the sliding tube when the proper adjustment has thus been carefully ascertained.

The most finished and perfect photographs, however, are produced by an achromatic lens, or one in which the error of chromatic aberration is corrected, by having it composed of two or three kinds of glass, of different dispersive power. It was stated in a former part of this work, when treating of "Coloured refraction, or the decomposition of light," that the length of the spectrum produced by prisms or lenses, varies when formed of different substances. Thus, if two lenses are made of the same focal length, the one being formed of flint glass, and the other of crown, the red and violet light caused by the length or diameter of the coloured image in the flint, will be to that produced by the crown lens nearly as 3 to 2. If, therefore, we make the focal lengths of the lenses in this proportion, the coloured spectrum produced by each will be equal; but if the crown lens be convex, and the flint concave, when placed in contact they will correct each other, and a pencil of white light refracted by the compound lens will remain colourless. Such is the principle of the achromatic lens, which is either single or compound, using the latter word in a different sense from that which signifies the combination of two or more different kinds of glass in one lens. The single achromatic lens is usually employed for views, and the compound for portraits. The former consists of one compound glass; the latter of a combination of separate achromatic lenses, placed at some distance apart. Till lately, the compound lenses were only imported from the continent; but now they are manufactured cheaper in England, and, in many instances, of even superior quality.

We have been thus particular in explaining these details, to enable the amateur in photography to cultivate the art with that intelligence, and knowledge of principles, which it is the object of this work to convey into every process of manipulation.

Hitherto our illustrations have been confined to sections. Fig. 8 is a drawing of Mr. Willats' improved camera, with

Fig. 8.



double achromatic combination lenses. This form of the camera is well adapted for taking portraits by the collodion process. Fig. 9 is a similar instrument, with single achromatic lens and revolving diaphragm. The prices of these most improved cameras, vary from ten to three guineas.

Fig. 9.

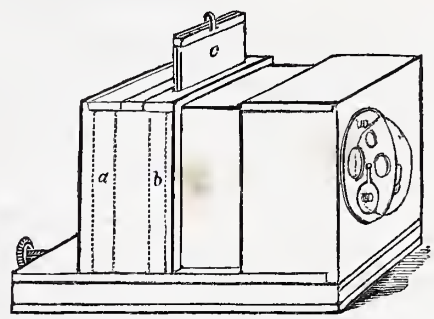
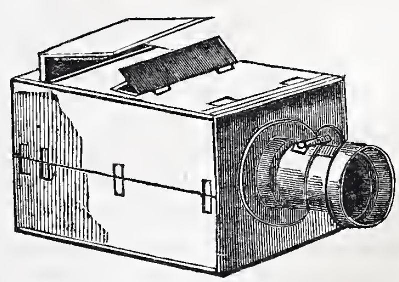


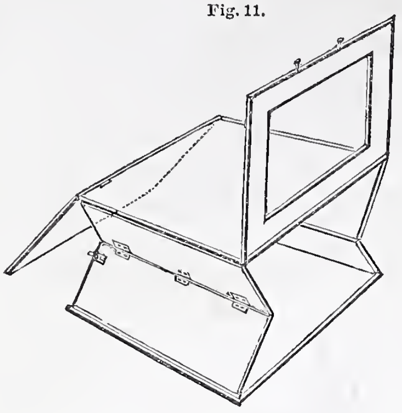
Fig. 10.



There are different forms of portable cameras, which admit of being folded up, and packed in a travelling case. Fig. 10 is a convenient form of this instrument, ready for use; and in

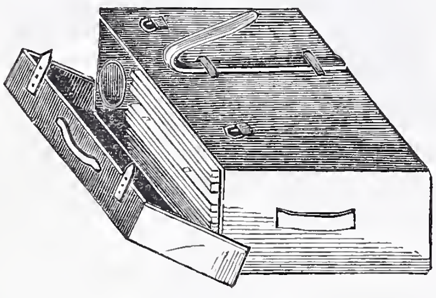
fig. 11 it is shown partially folded, when about to be packed, with the lenses, plates, &c., in the leathern travelling case, fig. 12.

Fig. 11.



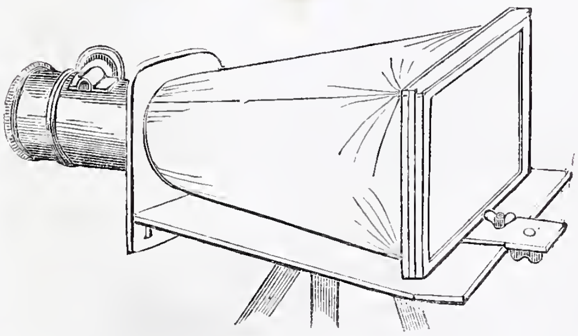
A collapsible camera, of peculiar lightness and portability, was shown at the Great Exhibition by Messrs. Willats of London. A perspective view of this apparatus, as ready for

Fig. 12.



use, is represented in the annexed engraving (fig. 13). The chief novelty consists in the expanding cloth body, and the simple method by which the paper or plate used can be placed at any angle that may be found best for obtaining a good general focus. The lenses are fitted with a fine rackwork

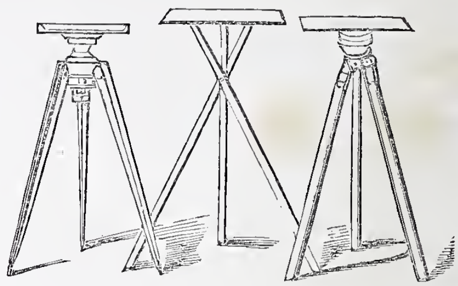
Fig. 13.



adjustment for correcting the focus, and can also be moved in a vertical direction, to bring the object to be copied in the centre of the field. To enable the operator to use lenses of different focal length, should he require them, the framework at the back of the instrument is mounted on a sliding plate, which can be clamped at any distance from the lens; and the whole camera is so arranged that it can easily and quickly be put together, or dismounted and packed for travelling, occupying less than half the space and weight of the old forms of camera. It is also alleged by the inventor to be less liable to damage from extremely hot climates, or moisture. This arrangement is stated to be best adapted for large cameras, and is especially recommended to travellers wishing to obtain large photographic views, without the encumbrance of a bulky apparatus.

Having thus enumerated the different forms of the camera used for photographic purposes, we leave the student to make his choice among them, in which he will, of course, be guided by special considerations. While on this subject we may add, that for the purpose of adjusting the camera to different heights, and to different angles of elevation, tripod stands are convenient, though not absolutely indispensable. Some are constructed of a portable form, for the use of tourists and travellers, and others are exclusively adapted for home use. The legs may be attached at the top to a brass ball-and-socket joint, and this adapted to the bottom of the camera by a screw plate. Some are furnished with compound legs, to insure greater steadiness. Three forms of such stands are shown in fig. 14. A few flat dishes, a pair of scales with glass pans, a

Fig. 14.



graduated glass measure or two, to contain about two fluid ounces, and a frame on which the photograph can be placed for the purpose of being washed, are the only additional apparatus which the student will find of essential advantage for the practice of photography on paper.

We are now in a position to describe the calotype process, which will naturally form the subject of the next chapter. In the meantime, we cannot more appropriately conclude the present, than by quoting an interesting correspondence which has lately passed between the presidents of the Royal Society and the Royal Academy, and Mr. Talbot, the patentee of the art of photography on paper. We stated in our first chapter on this subject (vol. i., p. 544), that photographic improvements, and, more especially, their general use and application, have been much obstructed in this country by exclusive patent rights; and that a recent attempt to establish a photographic society had failed, from the somewhat unreasonable claims of Mr. Talbot, in rigorously insisting on his monopoly. We stated, at the same time, that in subsequent negotiations connected with this subject, Mr. Talbot had manifested some disposition to relax the extreme rigour of his legal claims; and this, we are happy to state, has been confirmed by the following letters, which lately appeared in the *Times*:—

"London, July, 1852.

"Dear Sir,—In addressing to you this letter, we believe that we speak the sentiments of many persons eminent for their love of science and art. The art of photography upon paper, of which you are the inventor, has arrived at such a degree of perfection, that it must soon become of national importance; and we are anxious that, as the art itself originated in England, it should also receive its further perfection and development in this country. At present, however, although England continues to take the lead in some branches of the art, yet in others the French are unquestionably making more rapid progress than we are. It is very desirable that we should not be left behind by the nations of the continent in the improvement and development of a purely British invention; and as you are the possessor of a patent right in this invention, which will continue for some years, and which may, perhaps, be renewed, we beg to call your attention to the subject, and to inquire whether it may not be possible for you, by making some alteration in

the exercise of your patent rights, to obviate most of the difficulties which now appear to hinder the progress of art in England. Many of the finest applications of the invention will, probably, require the co-operation of men of science and skilful artists. But it is evident, that the more freely they can use the resources of the art, the more probable it is that their efforts will be attended with eminent success. As we feel no doubt that some such judicious alteration would give great satisfaction, and be the means of rapidly improving this beautiful art, we beg to make this friendly communication to you, in the full confidence that you will receive it in the same spirit—the improvement of art and science being our common object.

"ROSSE.
"C. L. EASTLAKE.

"To H. F. TALBOT, Esq., F.R.S., &c.,
"Lacock Abbey, Wilts."

"Lacock Abbey, July 30.

"My dear Lord Rosse,—I have the honour of receiving a letter from yourself and Sir C. Eastlake, respecting my photographic invention, to which I have now the pleasure of replying. Ever since the Great Exhibition, I have felt that a new era has commenced for photography, as it has for so many other useful arts and inventions. Thousands of persons have now become acquainted with the art, and, from having seen such beautiful specimens of it, produced both in England and France, have naturally felt a wish to practise it themselves. A variety of new applications of it have been imagined, and doubtless many more remain to be discovered. I am unable myself to pursue all these numerous branches of the invention, in a manner that can even attempt to do justice to them; and, moreover, I believe it to be no longer necessary, for the art has now taken a firm root both in England and France, and may safely be left to take its natural development. I am as desirous as any one of the lovers of science and art, whose wishes you have kindly undertaken to represent, that our country should continue to take the lead in this newly-discovered branch of the fine arts; and, after much consideration, I think that the best thing I can do, and the most likely to stimulate to further improvements in photography, will be, to invite the emulation and competition of our artists and amateurs, by relaxing the patent right which I possess in this invention. I therefore beg to reply to your kind letter by offering the patent (with the exception of the single point hereafter mentioned) as a free present to the public, together with my other patents for improvements in the same art, one of which has been very recently granted to me, and has still thirteen years unexpired. The exception to which I refer, and which I am desirous of still keeping in the hands of my own licensees, is the application of the invention to taking photographic portraits for sale to the public. This is a branch of the art which must necessarily be in comparatively few hands, because it requires a house to be built or altered on purpose, having an apartment lighted by a skylight, &c., otherwise the portraits cannot be taken in-doors, generally speaking, without great difficulty. With this exception, then, I present my invention to the country, and trust that it may realize our hopes of its future utility.—Believe me, &c.,

"H. F. TALBOT.

"The EARL OF ROSSE,
"Connaught Place, London."

It may be the opinion of some, that this concession would have come with a better grace at an earlier period. We congratulate the friends of photography, however, on the freedom which they now enjoy to cultivate the art without restraint; for the single exception, in the case of photographic portraits for sale to the public, is really of little moment: no one cares for portraits on paper, now that they are taken so beautifully on glass, by processes to be described hereafter. It is true that M. Le Gray says, "the future of photography is altogether in paper;" but we are convinced that the use of this material will long be confined to landscapes, buildings, and other inanimate objects. At the same time, now that it is freed from its patented restraints in England, we shall not venture to set limits to the beauty and variety of its future applications. Mr. Willats, in the preface to his recently published translation of M. Le Gray's work, remarks:—"Assuredly, photography on paper has made more progress in France than in England, a fact which is attributable, mainly, to the freedom of use enjoyed in the former country. It is there already employed for the purpose of illustrating books of travel, the first number of a beautiful work, 'Italie Monumentale,' being now on sale. A printing-office for the reproduction of positives in numbers, is on the eve of establishment; and the government has just engaged several of the more skilful photographists to take views of the more interesting of the ancient monuments scattered through the provinces. The Photographie Society, founded by M. Le Comte Montford, and the journal, 'La Lumière,' devoted to heliography, have done much to encourage and spread the knowledge of this charming art. At some future day, when photography is freed from its patents, if that day should ever come, we may hope to see it take the same high position in this country."

The day anticipated by the writer of these remarks, so far as concerns our emancipation from patent restraints, has already arrived, and we think we may venture to predict, as consequent on that boon, a rapid corresponding advance in the beauty, celerity, and perfection of photographic processes.

HORTICULTURE.

CHAPTER II.

ON THE FORMATION AND LAYING OUT OF AN ACRE GARDEN.

MANY country houses have the garden placed around them; but a garden is always more productive, if situated by itself and surrounded by a wall, and is, moreover, far less liable to suffer from the inroads of poultry, rabbits, &c.

A very low situation is improper for a garden, as fogs are most prevalent in such; and it is found that where fogs prevail, fruit-trees and vegetables suffer most severely from spring frosts, which render everything very late. Darwin, upon this head, remarks that Bradly "gives a decisive fact in regard to this subject. A friend of his had two gardens; one not many feet below the other, but so different, that the low garden often appeared flooded with the evening mist, when none appeared in the upper one; and, in a letter to Bradly, he complains that his lower garden is much injured by the vernal frost, and not the upper one. A similar fact is mentioned by Lawrence, who observes that he has often seen the leaves and tender shoots of tall ash-trees in blasting mists to be frozen, and, as it were, singed in all the lower parts and middle of the tree, while the upper part, which was above the mist, has been uninjured."

If practicable, the exposure should be to the south; and it is considered advisable to have an open aspect to the east. If the sun do not come to the garden until about ten o'clock, by which time it has acquired considerable heat, the sudden change of temperature thereby produced is extremely injurious, particularly to fruit blossoms.

The garden must be sheltered by means of plantations and forest trees, but these must not be placed so near as either to take anything from the soil of the garden, or let the rain-water drop from their branches into it. About a hundred and fifty feet from the garden wall is considered a suitable distance. These plantations should consist of sycamores, lime-trees, birches, larches, spruce, and balm of Gilead, firs, evergreens, oaks, &c.

A plentiful supply of water is absolutely indispensable to a garden, and this is a point too often neglected. If it can be obtained, the best supply is to be got from a streamlet flowing through the garden. When this is the case, a pool is made in the centre of the garden, and kept full by the stream. If the supply is derived from a well, two or three tubs or casks should be sunk in the ground, and the water that is to be used for watering the garden allowed to remain in them for a day, in order to get somewhat warmed.

The most common and convenient form of a garden is an oblong, and the best proportion is for the long wall to be to the short one as three to two, and the next best to that, as five to four. The importance of the discovery, by Mr. Hay, of the laws of symmetrical beauty, is not yet recognized; but when it is, and acted upon, its effect in making everything around us minister to our sense of the beautiful, will unquestionably be very great and very beneficial.

The garden should be surrounded by a wall, against which fruit-trees can be trained. It is believed that the south wall affords to the trees placed against it an increased temperature, equivalent to seven degrees of latitude; that is to say, a tree planted against a south wall at Edinburgh, has a temperature equivalent nearly to that of Paris. The temperature of the north wall, on the other hand, is lower than that of the open air, and fruit-trees placed against it are longer in bringing their fruit to maturity than they would be if placed elsewhere. We can, by taking advantage of this, retard the ripening of cherries and currants, and thus prolong the supply over a greater length of time.

It is proper to make the walls of different heights, in order not to let the garden have the appearance of a large box. The north wall may be raised to the height of fourteen feet, the east and west to twelve, and the south one to ten; but if the expense of the height is grudged, lower ones will suffice. Bricks are considered better than freestone, as absorbing much heat, and affording in their interstices many places where nails can be driven in; but in the Caledonian Horticultural Society's garden, where some of the walls are built of brick, some of sandstone, and some of whinstone, the trees upon the last were found to have the most superior growth and earliest maturity.

Fruit-trees should be trained on both sides of the wall, and at a little distance from the outside wall there should be some kind of a fence, a ha-ha, or an iron railing. The space between the wall and the fence is part of the garden, and is technically called a "slip."

If it is more convenient, wooden walls will be found to answer very well. In constructing them, the great point to be attended to is, to see that their joints fit close, so as not to allow currents of air to pass through them.

It is, we should mention, considered proper to give the wall a short coping. Perhaps one that projects an inch is about sufficient.

The site of the garden being fixed, the wall erected, and the shelter planted, the ground, if not drained (as, however, it most likely will have been), must be drained. The next step to be taken is to have it trenched to a depth of two feet. Almost every kind of soil will be the better of having from one to two hundred bushels of lime to the acre mixed with it during this process, and subsequently of receiving about forty bushels of crushed bones.

During the trenching, all the stones must be removed; and perhaps the best, and, in the end, the cheapest, way is to pass all the earth through a riddle.

Then comes the laying out of the area. A border is always left, next to the wall, of about fifteen feet in breadth, and around the margin of this border there is a walk. The middle part of the garden is divided by straight walks into rectangular compartments. Box, or some other edging, bounds the walks, and these compartments are further divided by gooseberry and currant bushes, and dwarf fruit-trees trained on espalier rails. All these are points that require a little consideration.

The breadth recommended in most works upon gardening for the walks, is six or seven feet, but in gardens such as that to which we refer, from three to four feet is amply sufficient. Walks are made of gravel, of sand, of grass, and sometimes, but rarely, of large flags of stone. All the earth occupying the space allotted to a walk is thrown away, and a foundation laid with broken stones. When, as is the common plan, gravel is intended to form the surface, it is spread on the top of these to a thickness of about six inches. All the large stones, we should observe, should be carefully picked out from the gravel before it is spread upon the walk. The surface of the walk should be made slightly convex.

Whenever gravel can be obtained at a sufficiently cheap rate, it is employed for making walks. Sand, however, does well enough, and even coal ashes are sometimes used. Grass walks are extremely troublesome to keep in order, and are, moreover, in wet weather, very damp to the feet. In gardens laid out in a very formal style, a stone-flag walk looks very well, and always allows a promenade to be taken without wet feet.

Every garden of the size to which we refer should have edgings, although in larger ones they are now frequently dispensed with, and nothing is so good for the purpose as box-dwarf. It requires to be carefully cut, from time to time, to prevent it attaining an excessive size, in which case it not only disfigures the garden, but is a sad harbour for slugs and other vermin.

The espalier rails run across the centre, or both ways across the centre of the garden, there being, however, a border between them and the walk. "Espalier rails," says Neil, "in their simplest form, are merely a row of slender stakes of ash or Spanish chestnut driven into the ground, and connected by a slight rod fitted at the top. In some gardens the perpendicular rods are fastened into two horizontal rails, supported by strong posts, which are battered into stones. Cast-iron rails have also been proposed. The framework is sometimes inclined to the horizon, or adapted to a sloping bank, as in the gardens of the Earl of Selkirk, at St. Mary's Isle, where the trees, although so trained more than forty years ago, are still in a healthy condition, bearing abundant crops of excellent fruit. In other cases, the framework is placed flat like a table, and when there is plenty of room, this proves a good arrangement." The second of these kinds of espalier rails appears to us by far the best.

A number of dwarf standard trees are now almost invariably admitted into the body of the garden: but tall standards are in no case admissible. Of late, there has been a tendency to banish the gooseberry bushes and the currants from the side of the main bed, and to put them into separate places of their own. This, however, in a garden of the size to which these observations belong, is certainly not advisable.

When the walls have been built, the ground drained, trenched, limed, and the area divided, the next step is to plant the fruit-trees against the walls. Upon another occasion we will venture to offer a few observations on this head. The gooseberry bushes, &c., are then planted, and the garden is ready for being cropped.

Subsidiary to a garden, both as affording fruit and as a place of recreation, is the orchard. Properly speaking, an orchard is not surrounded by walls, and the soil is not under the spade, but in grass, and the trees are tall standards. An orchard should, by means of plantation, be sheltered from the most prevailing winds. In this country, the most prominent place in an orchard is given to apple-trees; then come pears, a few plum-trees, cherry-trees, guines, and, if considered desirable, a quince, medlar, and walnut-tree, and a filbert plantation. The distance at which the larger trees should be planted is, perhaps, about forty feet, and that of the cherry and smaller ones, thirty.

Viewing gardens and orchards as places of recreation, a number of characteristic decorations are very properly admitted into them. Arbours, moss-houses, bark-huts, and the like, may be made elegant rustic buildings, and also afford a shade from the sun in summer, while alcoves can be constructed so as to be fully exposed to the sun in winter, and thus supply a temporary resting-place in that season. If a supply of water can be obtained from a sufficiently elevated source, a fountain is a very agreeable ornament to a garden; and, in its place, if there is not such a supply, a pond with aquatic plants may be substituted. Sun-dials are very appropriate and pleasant garden decorations. Monuments, pieces of sculpture, and the like, are suitable enough in large grounds, but in a garden such as the one to which we all along refer, they are quite out of place. If any are admitted, they should be either grotesque ones, or out of the way curiosities, as Chinese or Indian gods. Rock-work, also, in small gardens rarely looks well; and, indeed, to make rock-work so as to have a good effect, is always a very difficult task.

NATURAL PHILOSOPHY AND CHEMISTRY.

CHAPTER XXI.

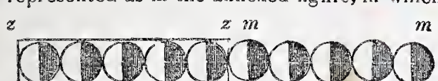
ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART I.—VOLTAIC ELECTRICITY.—*Concluded.*

121. Having in the preceding chapter afforded the reader a view of the inductive action of ordinary electricity, and generally of the nature of the inductive influence exercised by one body in a positive or negative electrical state, upon another body in a dissimilar electrical state, at a greater or less distance; it is presumed that he can now better understand the nature of the inductive influence of voltaic electricity, or in other words, the means whereby the electricity of the voltaic circle is assumed to be produced and propagated through liquid conductors.

122. There are various theories in existence respecting the peculiar mode by which the inductive influence operates in the development and propagation of electricity in voltaic arrangements; some of them are extremely ingenious, and assuming the general views of the theorists concerning the nature of the electric force to be correct, they would appear adequate to the satisfactory explanation of the volta-electric development and mode of action; but unfortunately these views when closely examined, cannot be accepted as true interpretations of the mysterious phenomena of electricity. They only enable us to classify certain facts, and bring them within the scope of numerical calculation; but they utterly fail when we attempt to apply them as generalizations which shall include *all* the phenomena that recent research has developed. Those theories are however upheld by so many, that it would be an act of injustice to the reader, to omit laying before him the opinions respecting volta-inductive action, which in this country have hitherto been deemed the most rational; particularly where the views brought forward present many curious and important points, likely to be serviceable in future inquiries.

123. Dr Kane, whose scientific abilities, and education under some of the most distinguished continental philosophers, entitle his opinion to considerable respect, considers a slip of zinc forming one of the elements of a simple circle, in the light of a magnet possessing opposite polarities at each extremity, and that also like the magnet, it must be made of a vast number of particles, each having its positive and negative poles. In this view, the condition of the slip of zinc may be represented as in the annexed figure, in which *z*, *z*, is



the slip of zinc, and each circle therein represents a particle, the dark hemisphere of each being in a different electrical condition to the light one, upon immersion of the slip in an electrolyte,—say muriatic acid. The particles of the acid are represented by *m*, *m*—the halves being also in different electrical conditions. These last are, of course, to be considered compound particles, consisting of chlorine and hydrogen, the chlorine or light portion of each circle being negative, and the hydrogen or dark half, positive. In this condition that half of the zinc particle nearest the liquid becoming positive, and that half of the nearest particle of the liquid being chlorine, becoming negative, union would immediately result, if no other action interfered; but the chlorine is held back by the positive molecule of hydrogen with which it is combined, and the action is thus balanced. If then, a plate of copper be introduced, and connected with the zinc so as to complete the circuit, decomposition occurs, which is explained as follows. It will be observed that in the preceding arrangement, the inductive excitement is most active at the point of junction of the fluid and metal, and diminishes as the particles increase in distance from that point; but when the circuit is completed, the action becomes equally powerful all through; the particles of copper assume a condition similar to those of the zinc, but in the reverse order; that half of the molecule next the acid being negative, and that which is in contact with the zinc becoming positive; and hence a complete chain of inductively polarized particles being established, precisely such as are represented by cuttings of silk thread, which convey frictional electricity through oil of turpentine. Under such circumstances, the electricities of the adjoining particles of zinc and chlorine combine, and their neutralization is followed by that of the entire chain; the adjacent particles of zinc and chlorine then unite; the hydrogen disengaged combines with the second particle of chlorine; its hydrogen with the third, and so on, until that particle of hydrogen nearest the copper, having no remaining particle of chlorine to combine with, is evolved under the gaseous form.

124. Dr Kane resolves this reaction into three distinct stages; 1st, The mutual excitation by inductive polarization of the zinc and muriatic acid; 2d, The completion of the chain of inductively polarized particles by the intervention of the copper plate and connecting wire; 3d, The passage of the current and the consequent decomposition of the liquid electrolyte in the cell, the chlorine being evolved upon the zinc with which it enters into combination, and the hydrogen being eliminated upon the surface of the copperplate. Dr Kane concludes that the source of the current is therefore *not* to be found in the decomposition of the acid—for it *precedes* it—but that the quantity of chemical action in the generating cell is proportional to the quantity of electricity which passes, inasmuch as it is produced entirely by its agency. He conceives further, that it is only where the replacement of one body by another occurs, that the establishment of the chain of inductively polarized particles becomes necessary; for that, in such case, the particles of zinc and hydrogen which become oppositely electrified, have no power to combine, and hence cannot be restored to neutrality unless by the medium of a third body to which both may impart their excitations.

125. Concurring fully in the opinion of Dr Kane, that the voltaic current does not arise from the transfer of elements which takes place in the generating cell; but, on the contrary, that the transfer of elements results from the passage of the current—indicating its direction and measuring its amount; we cannot agree with him in attributing the origin of the current to that peculiar arrangement and electrical condition of the molecules of the zinc and electrolyte, which he assumes to be necessary.

126. That the mass of zinc constituting the zinc plate becomes polarized on immersion in any electrolyte, cannot admit of a doubt; and that the particles constituting the mass assume a similar condition, is a natural conclusion; but that the compound molecules of the electrolyte are so constituted as to present (as in the case of muriatic acid) a surface of chlorine on one part, and a surface of hydrogen on another part of each molecule; or that the elements constituting the molecule can preserve their original individuality while forming a third substance utterly distinct in its nature and attributes from either, is an assumption we cannot admit. On the contrary, we believe, that in every compound molecule, there is such an intimate intermixture of the particles of each element when combining, as completely to annul the notion of distinctness of any one part or surface of a molecule from another part. It will be observed that we are here speaking of the condition of a compound molecule, not of the condition of the congeries of atoms of which the particles of the elements forming it may be assumed to be composed. The very fact of a compound molecule consisting of two or more elementary substances, proves it to be divisible; and if it were possible—by our limited powers—to divide it into parts corresponding in size with the elementary particles composing it, there can be no doubt but that each portion would contain the different elements composing the original molecule in similar proportions. How then can we suppose a mole-

cule to be in one part chlorine, and in another hydrogen? But this is what we must suppose, if we entertain Dr Kane's views of inductive polarization; besides, inasmuch as we cannot suppose the chlorine or negative sides of the molecules of the electrolyte to be all turned, in the first instance, towards the positive particles of zinc, we must, according to Dr Kane's views, conceive some of those molecules, adjacent to the zinc surface, to be turned round so as to present the proper surface to the action of the zincous particles; but by what power this revolution is to be effected, it is not easy to perceive. For, assuming the hydrogen or positive sides of some of the molecules to be adjacent to the zincous surface in the first instance, the effect of induction would be to polarize positively the remote or chlorine side, and polarize negatively the adjacent one; but in order to effect union with the positive particle of zinc, that state of polarization of the chlorine side must be reversed, and it must be made to reassume the negative condition it possessed before immersion of the zinc in the fluid. It is evident that this counteraction cannot be brought about by the same influence which previously caused the positive polarization of the chlorine. Upon Dr Kane's assumption, it therefore remains unaccounted for. How much easier is it to conceive, that the atoms of chlorine being equally diffused throughout the molecule—and retaining in that state of diffusion the negative condition peculiar to them—are, whatever may be the position of the molecule itself in regard to the zinc, in a position to directly attract and be attracted by the zincous particles in their vicinity!

127. Professor Graham's views of the propagation of electricity through the voltaic circuit, and also of the molecular constitution of the metals and fluids constituting the circle, are not only peculiar, but extremely ingenious, and may, therefore, be briefly stated as follows:—Mr Graham assumes that zinc and hydrochloric acid are both composed of particles which are susceptible of a polarized condition like the particles of soft iron, in which the extremities of each particle assume opposite attractive powers: the polar molecule of hydrochloric acid is the chemical atom, consisting of one atom of chlorine, and one of hydrogen, associated together. Hydrochloric acid is here taken as a fair type of that class of substances which are available as exciting agents, which agents must always be saline bodies in the general sense,—that is, compounds of a salt-radical, such as chlorine, with a basyle, such as hydrogen, or a metal. The chloride of copper, chloride of sodium, chloride of ammonium, or chloride of any other basyle, may be substituted for hydrochloric acid, though not all with equal advantage; and the chlorides of basyles may be replaced by their iodides, sulphates, nitrates, and salts of other acids, as exciting fluids, provided they possess mobility of their particles, so as to assume the constitution of a polar chain. The polar molecule of zinc is likewise assumed to possess the binary or saline structure, which may be more definitely described by assigning to it three atoms of metal; two of which, conjoined, form the salt-radical, or chlorous atom, and one the basyle, or zincous atom. The metallic and fluid portions of the circle are thus assimilated in constitution, and decomposition can be propagated in any direction through the fluid portion of the circle, owing to the mobility of each particle; but decomposition may also be propagated in both directions through a chain of metallic molecules, although solid, and therefore without the same power of adjustment. To explain this, it must be assumed that decomposition can easily take place in the metallic molecule itself; that in the arrangement of its three atoms, A, B, and C; A forming the zincous element, and B + C the chlorous—a change can occur in which C becomes the zincous element of the sali-molecule, and A + B the chlorous; the three atoms constituting the molecule being of one metal, and like nature, may admit of this change by a substitution of one atom for another.

128. Mr Graham adduces many circumstances in favour of the existence of this assumed condition of metals—for instance, in iron, the magnetic property is confined to the metal itself, and one degree of oxidation, viz., the black oxide, with its corresponding sulphuret. This degree is that into which iron most readily passes. It consists of single equivalents of the protoxide and peroxide, or of three atoms of iron and four of oxygen. Here the metallic sali-molecule is not disturbed in the formation of the black oxide; the zincous element, Fe, combining with one equivalent of oxygen to form $Fe\,O$; and the chlorous element, Fe_2, with three equivalents of oxygen, to form $Fe_2\,O_3$; and these two oxides themselves remain in a state of union. Metallic iron having, therefore, similar magnetic capability with the black oxide, or the loadstone, which has three atoms of metal in its molecule, may fairly be supposed to have three also.

129. This assumed condition is also supported by the electrical effects consequent upon the contact of different metals; for, admitting the reality of the sali-molecular structure of metals, one metal may be affected by another metal, as well as by a salt, or acid—the constitution of all being the same; but the phenomena of the contact of metals stop short of chemical combination, the chlorous element of the copper molecule attracting its own zincous element the less that it attracts likewise the like element of the zincous molecule—but not abandoning the former to combine with the latter. Such phenomena belong to the open not to the closed circuit. Sulphur, dry acids, peroxides, &c., disturb the molecular affinities of the metals they touch, in the same manner. The sali-molecule of the highly negative metals, gold, platinum, mercury, &c., contains a strong salt-radical, united with a weak basyle, and resembles hydrochloric acid and the hydrates of the strong acids; while the sali-molecule of the highly positive metals, potassium, zinc, &c., contains a powerful basyle, and weak salt-radical, like the hydrated alkalis.

130. Applying these notions to the propagation of electricity through the simple voltaic circle, it would appear that, when the zinc is pure, the zincous and chlorous attractions of the adjacent particles of zinc and fluid are not sufficiently intense to produce detachment of one element from another; but, if a copperplate be introduced into the electrolyte, and connected with the zinc, the particles of the acid assume chlorous and zincous poles as before. So do those of the zinc; and the chain of polarized molecules is now continued through the zinc and connecting-wire to the copper; the exterior particle of which comes thereby to present a chlorous pole to the acid. The contiguous particle of acid is thus exposed to a second induction from the chlorous polarity of the copper, which increases the zincous polarity of the side of the acid particle next the copper; and, therefore, aids in increasing the polarized conditions already assumed by the chain of acid particles between both metals. An endless chain of polarized molecules, symmetrically arranged, is thus formed, such as exists in a magnet whose poles are united by a lifter, in which every particle in the chain has its own polar condition elevated by induction, and at the same time does itself react upon and elevate the polar condition of every other particle in the chain. The result is, that the primary attraction of the zinc atom next the acid for the chlorine of the contiguous acid particle, is increased to the degree of intensity, at which the resistance to the new combination is overcome, and the zinc and chlorine particles unite; but, in a circle of polar molecules, the intensity of the polar condition is determined by that of any one molecule, and is therefore the same in every element of the circle. The molecular polarity must therefore increase to an equal degree throughout the chain; and therefore a similar change to the first must occur through a chain of particles of acid of any length, until at last the copper is reached, when the last acid particle yields its hydrogen to the chlorous pole of the copper; but this hydrogen, not being capable of uniting with it, is liberated as gas upon the surface of the metal.

131. Although the preceding views of Professor Graham exhibit proofs of deep consideration and vast ingenuity, it must be admitted, that there is too much of artificiality in their construction to warrant our placing implicit reliance upon the existence of any such molecular state in bodies generally. It is not at all improbable that, in the formation

of a new substance by the combination of two or more elements or compound substances, the atoms of each element or substance may assume a peculiar arrangement in the formation of the compound molecule, which may be, and most probably is, occasioned by a balancing of the electrical forces peculiar to each element; but, that such a condition of the particles of an uncombined element, in its natural electrical state, exists, has yet to be proved. At all events, we must not suppose that there is constancy in any particular molecular arrangement of a metal; for, if so, the polar condition of its molecules could not be reversed so easily, as we are aware when the direction of the induction accompanying and effecting it is altered.

132. Mr Faraday supposes the zinc and hydrochloric acid to have each polarizable molecules, whose polarity is developed by their approximation or contact. Each molecule is assumed to possess the positive and negative electricities, which have contrary powers, and are in a neutralized state in the natural condition of the molecule. The contact of the zinc is supposed to separate the combined electricities of the acid molecule, its atom of chlorine next the zinc becoming negative, and its atom of hydrogen positive. The electricities of the zinc molecule are similarly separated, that side of the molecule next the acid assuming positive electricity, and the remote side negative. The positive and negative electricities, being contiguous, attract each other, and are finally neutralized by the union of the zinc and chlorine molecules to which they were attached. Inductive polarization is, therefore, in this view, equally assumed as occurring previously to chemical union, only—according to Faraday's view—the polar forces are the two electricities; while—according to Graham's—they are the two chemical affinities. In Faraday's view, the propagation of the inductive effects to a distance, or across an intervening stratum of water rendered conductive by sulphuric acid, is accomplished by induction and polarization of the intervening particles, and the convection of the voltaic charge can therefore be only effected by decomposition of the water, which admits of the oxygen and hydrogen travelling in opposite directions, separating from one particle, and combining with another, throughout the chain of previously polarized particles, till the last particle of hydrogen gives up its charge to the platinum, and the oxygen to the zinc, with which the latter combines, while the former passes off in its peculiar elastic form.

133. The convection cannot, therefore, in this view, be considered as the transfer of a single force in one direction; but of two forces in opposite directions, in consequence of which the electric current has been designated by Mr Faraday, "an axis of power, having contrary forces exactly equal in amount, in contrary directions." It is unnecessary here to remark, after what has been previously stated, that the transfer of force can be much more satisfactorily and naturally explained without the aid of two electricities.

134. An attentive and unprejudiced consideration of the various facts set forth in this treatise—facts collected from the investigations of the most distinguished philosophers at home and abroad, as well as from private research—must lead to the adoption of the following conclusions:—

1st. That electricity is associated with all bodies in nature, whether elementary or otherwise; but with no two bodies, in their natural state, in equal proportions.

2d. That every substance requires a certain definite amount of electricity for its constitution, and the preservation of its natural properties.

3d. That electricity, like any other fluid, endeavours to attain a state of equilibrium, and to diffuse itself equally. That, therefore, when two or more elements unite in a compound body, each element does not preserve its natural electrical condition; but that the total quantity of the electricity of the several combining elements is equally diffused throughout the mass.

4th. That diffusion may take place upon the contact of two or more substances in different electrical conditions, without necessarily inducing a chemical combination of those substances, and the formation of a new body.

5th. That the ordinary contact of two or more bodies, in different electrical states, is sufficient to produce induction, diffusion, or, under certain circumstances, the passage of a current; but not sufficient to admit of chemical combination, or the production of a new substance.

6th. That the attraction manifested between two uncombined elements—two elements previously combined with other elements—or between two or more compound substances in different electrical conditions—is a consequence of the natural tendency of electricity to diffuse itself equally through matter.

7th. That the state denominated inductive polarization is an artificial condition of the particles or molecules of bodies, produced by the tendency of electricity to equal diffusion, and perceptible chiefly in those cases where the electricity, although existing in more than the natural proportion, or possessing extraordinary tension, has not, as yet, accumulated sufficiently, or acquired sufficient tension to enable it to separate itself from the matter with which it is associated, and overcome the resistance to conduction of neighbouring matter, whose particles, through a peculiar molecular arrangement, are, more or less, insulated, one from the other.

8th. That such a quality as a repulsive electrical force, between the molecules or masses of matter, does not, in reality, exist; and may be in all cases resolved into its opposite attractive force, which develops its action in different modes and degrees;—first, by the tendency of the superabundant electricity of one particle or mass of matter to unite itself to fresh matter, which is evidenced by induction; secondly, by its actual abandonment of one substance for another, which is manifested by the electric spark; thirdly, by the motion of a charged body towards that which is least electrified in its vicinity, which is perceptible material attraction, or preference; and fourthly, by that imperceptible motion of the elements or particles of different substances towards one another, and their intimate union in a new arrangement and new body, which is denominated chemical combination. Keeping these several forms of attractive force in view, we can easily comprehend how the separation of two moveable bodies—such as two electrified pith-balls, or two strips of gold leaf, &c.—to a greater distance from each other, may occur without the existence of any actual repulsive force between them; for, inasmuch as electricity has a constant tendency to equal diffusion, it will induce the matter in which it exists in excess to move towards any other matter in its neighbourhood containing a less proportion; and, similarly, the latter towards the former. Two pith-balls similarly charged will, therefore, assuredly not move towards one another; but in opposite directions, or in whatever direction there is the greatest likelihood of their superabundant fluid finding uncharged matter on which to diffuse itself. This is apparent repulsion; but, in reality, is nothing more than an attraction between the charged matter and some other matter within the circle of attraction not charged; or, if charged, not to so great an extent. It is proper here to guard the reader against confounding the resistance of each particle of a mass of matter, under certain conditions, to a nearer approach of contiguous particles, with repulsion, as generally understood; the non-existence of the latter quality not in the least affecting the existence of the former, upon which mainly depend the solid, liquid, and gaseous conditions of substances.

9th. That the copper or negative element of the circle performs other functions besides that of conduction; and that the terms "generating" and "conducting," in their restricted sense, have been very improperly applied to the two metallic elements. We have seen that the ordinary contact of different metals, or even of the same metals in different electrical states, produces, in all cases, induction; in some, diffusion; in some, transfer, or current; and in others, two, or the entire of those actions combined. We have also seen that immersion of a metal in a fluid, and the fluid-metallic contact thence arising, produces disturbance of the electric equilibrium, and its consequence, inductive polarization of

the particles of the metal in contact with the fluid ; as also a difference between the general electrical state of that part of the mass of metal in the fluid, and that part out of it. This inductive action affects also the molecules of the electrolyte, and the negative as well as the positive metal. Hence, if a strip of zinc be partly immersed in hydrochloric acid, its natural state of electric equilibrium becomes disturbed. The electrical state of one portion of the metal is exalted ; that of another portion debased. So also in regard to the acid. But although this excess or exaltation of the electrical condition of one part of the metal disposes its particles to enter into combination, it is not sufficiently high to enable the zincous particles to overpower the attraction already subsisting between the elements of the fluid ; in which state of things, the molecules of the fluid and particles of the zinc are in a state of electric tension. If, then, under these circumstances, a plate of platinum be immersed in the same liquid, but not in contact with the zinc, an increased degree of tension of the molecules of the fluid will be the result ; for the contact of the negative platinum will augment the plus-polarization of the liquid. That portion of the platinum, external to the fluid, will assume an opposite state to that of the portion in the fluid ; and, upon establishing metallic contact between that portion and the zinc, this contact so exalts the tension of the zincous particles in contact with the electrolyte, that the force of attraction between the elements of that electrolyte is at length overcome, and union between the negative element of the fluid and the positive zinc is the consequence. Thus we see that the platinum not only performs the function of a conducting metal, but also equalizes and enhances the inductive polarization of the liquid, thereby promoting its decomposition ; and furthermore, that, by contact, it exalts the plus-polarity of the zinc, thus bestowing upon it greater power to overcome the resistances in the circuit.

10th. That the origin of the current is to be found in the disturbance of the original electric equilibrium, by the inductive and attractive force of the highly positive zinc ;—the former acting upon the molecules of the electrolyte ; the latter upon the negative element of these molecules ; this disturbance being increased by the inductive and attractive force of the negative platinum ; the first influencing the molecules of the fluid—the second, the positive element of these molecules ; and that the electricity which actually passes, is the superinduced electricity of that portion of the electrolyte contiguous to the negative metal.

11th. That that peculiar modification of developed electricity termed " voltaic" must be considered, upon the various grounds previously set forth, to depend upon this general law, viz.:—That dissimilar material molecules or elements attract each other at insensible distances, with forces proportioned to the difference between their natural or artificial electrical conditions.

135. We have now arrived at the termination of the first part of our view of the present state of Voltaic Electricity and Electro-magnetism, and cannot conclude without the expression of a hope that, considering the limits within which we have been obliged to restrict ourselves, in a publication embracing so many equally important, as well as practically useful subjects, the sketch we have given contains an intelligible view of the present state of our knowledge of the laws and mode of action of voltaic electricity. We have done our best to separate the grain from the chaff, and to disencumber the science from the enormous mass of crude and antiquated theories by which it was oppressed. We have also found ourselves justified, by the results of our private investigations, in bringing before the reader some new matter and new views, of which the truly valuable mathematical researches of Mossotti and Ohm have formed the groundwork. Those views we shall be enabled still further to elucidate and support in the second part of this treatise, which will embrace the subject of Electro-Magnetism.

BOTANY.

CHAPTER III.

OF THE ROOT.

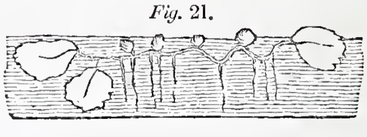
Having gone over, in the last chapter, the simple organic tissues of which vegetables are composed, we are prepared now to commence to *organology*, or the examination of the various *compound organs* of which the plant consists, and which it requires for the due performance of its functions. The principal of these are the root, stem, buds, leaves flowers, fruit, and seed.

The Root is that part of a plant by which it is attached to the soil, or substance on which it vegetates, and is the principal organ for the supply of nourishment. It is the lower extremity of the plant, by means of which it is fixed to the ground or place on which it grows, preventing its being torn up or upset by animals or by the wind ; absorbing nutritious matter for its support, and giving out a portion of what may be either useless or positively noxious.

At or about the same time that the ascending axis or stem of a plant seeks to rise toward the light, from the seed which has been placed within the earth, does the opposite extremity of the seed or bud bury itself in the earth, and become a root, with a tendency downwards so powerful, that nothing can overcome it. Correctly speaking, nothing can be considered a root except what has such an origin ; for those roots which are emitted by the stems of plants, as in the banyan tree, are in reality the roots of the buds above them. Nevertheless, it is extremely common for botanical describers to confound subterranean stems or buds with roots.

Independently of its origin, the root is distinguished by several unvarying characters. Its ramifications occur irre-

Fig. 21.



gularly, and not with a symmetrical arrangement; they do not, like branches, proceed from certain fixed points, which are buds, but are produced from any points of the root. Thus, roots have no scales, leaves, or other appendages, nor do they even indicate upon their surface, by the remaining scars, any traces of such having existed ; all underground ramifications having scales on them, being really stems, by whatever names they have been called. The only appendages which roots have ever been found to have, are such things as the little floating bladders found in the Bladder-wort (21), by which the plant is supported on the surface of the water.

(The above two paragraphs are taken from Lindley, with slight alterations.)

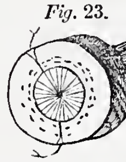
Almost all plants are possessed of roots, excepting only some of the simplest, which are fitted to absorb their nourishment through pores placed all over them, and have no distinction of stem, or root, or leaves. Although it has been said that the root is a means of fixing them to other objects, there are some which are unattached, as in the preceding figure, hanging down into the water, and the same is the case with some of the seaweeds. Some are attached to other plants, from which they abstract nourishment, thus doing them a great deal of harm, as the misseltoe, and many of those plants in hot climates belonging to the order of *Orchideæ.* Some of these have their long roots hanging down from the branches of the trees on which they are fixed, deriving nourishment from the warm moist atmosphere, highly loaded with vapour. Indeed the common ivy might be given as an example of a parasite, for although it has always a root in the ground, still it sets its radicles or little rootlets into the tree to which it clings, so as ultimately to injure it, causing it to wither and die.

The root presents two parts, sufficiently distinct, the descending stem, and the radicles.

The *descending stem*, or *caudex*, is the part with whose ordinary elongated form we are familiar, in the carrot and radish, and the firm woody roots of trees, and frequently passes far down into the earth. It is of a fibrous texture, like the stem, presenting long fibres, on which its strength and toughness depend, intermingled with a great many vessels, and presenting also like the stem medullary rays, radiating from the centre. The bark is thicker than on the ascending stem, and is frequently soft and fleshy. The red part of the carrot as seen in fig. 23, is the bark of the root, and has a kind of cuticle investing its outer surface.

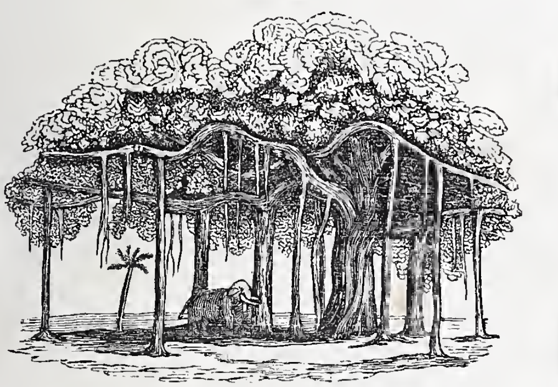
Fig. 22.

Fig. 23.



In woody plants, the stem and the root are very similar in texture, and interchange with one another. Thus an ash-tree is seen growing on the rotten stump of an old pollard willow, where its seed has fallen and taken root; and its roots have penetrated through the rotten old stump, until they have arrived at the earth, and fixed themselves also into it. By and by, the old willow rots away and falls to pieces, when the roots of the ash, now left exposed to the air, become coated with a green bark, like the rest of the stem, instead of the brown covering which hitherto invested them while holding the station of roots. Besides, it is not uncommon to see roots arriving at the surface and becoming *suckers*, rising into young stems, as every one has seen in the cases of the poplar and the plum. Again, the converse is occasionally seen, that branches send down roots towards the earth, which by and by fasten themselves, and become changed into new stems. The Banyan tree (Ficus Indicus) fig. 24, does this, and forms an extensive arcade, of immense size, a specimen having been known which covered a surface of 350 feet in diameter, with 50 or 60 stems. In the drawing, many roots are seen hanging down, which are on their way to the earth, so that they may fasten, and become additional stems.

Fig. 24.



The middle or fibrous part of the root, instead of becoming elongated, is sometimes much enlarged, or rounded, as in the turnip, still being covered with a bark, which peels off. It may be succulent and cellular, tough and fibrous, or firm and woody, but always contains a large proportion of vessels running through it.

The *radicles*, or little fibrils, which hang from the roots, are the essential parts, the real roots; they are always found in vegetables, because it is through them that nourishment is enabled to arrive at the plant. If a root be cut across, these are seen penetrating the bark, and reaching the central part, as in fig. 23. At the end of each fibril of the root is an enlargement full of pores, like a little sponge, through which the fluids pass into it. The necessity for the absorbing power of these sponges is proved by a simple experiment. Take a radish, and bend it, and put it in water, so that the bent part may be in the water, but the radicles out of it, and no absorption will take place, but the plant will fade away. Having been satisfied of this, put the end of the root now in, so that the radicles with their sponges have access to the water, and it will very soon revive and begin to grow.

These little fibres of the root have a wonderful power of insinuating themselves into every place from which any nourishment can be extracted. Plants of many kinds, and even trees, are seen living upon apparently bare rocks, their roots inserted into the clefts and fissures, where one would think that nothing could be absorbed except the drops of rain which the shade had prevented from being evaporated. The misseltoe, a parasite which is found upon old apple-trees, never takes root in the ground itself, but preys upon the juices which the apple-tree is appropriating to itself, striking its radicles through the bark, to its inner surface, where the *proper vessels* are most numerous (as was explained in chap. ii. p. 35), running in the inner layer, for the purpose of depositing the materials for the new outer layer of the wood.

The upper part of the root is the *crown*, *neck*, or *life-knot*, where the root and stem join, and which perhaps can scarcely with propriety be said to belong to either. From this, in those perennial plants which die down to the ground in winter, the new stem shoots up again in the succeeding spring. When the root has no *tail*, the fibrils spring from the neck or crown, as we see in the hyacinth, (fig. 25), where it is a flattened part with a somewhat projecting rim, just below the bulb.

Fig. 25.

It will be proper now to take a look at the various *forms* of roots, as these are sometimes referred to in describing the difference of species of the same genus. In speaking of these, I shall mean the parts which are found below the ground, without entering on the debatable ground of stem and root, where they seem sometimes to encroach on one another's territory, the root rising above the ground, or the stem descending below it.

The *fibrous* root may be either simple (26), as in many monocotyledonous plants, or *branched* (27), as in the grasses,

Fig. 26.

Fig. 27.

Fig. 28.

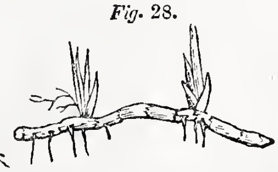
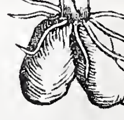


Fig. 29.

Fig. 30.

Fig. 31.



or may be *creeping* (28), as that of the club-rush, which forms a great portion of the fibrous part of peat. Or the root may be fleshy, and put on several different forms; *fusiform*,

or tapering, like the radish (22), *abrupt*, as if the end had been bitten off, as the scabious (29), or *tuberous*, like that of

Fig. 32.

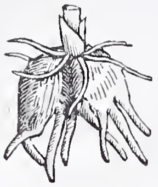


Fig. 33.

Fig. 34.

the potato (30). This last, however, is rather an addition to the root than the root itself; for in the spring, when the potatoes lying in the cellar begin to grow, its long roots are seen striking out from the eyes in the tuber. All the plants of the Orchis tribe have tuberous roots, which are frequently divided in such a peculiar manner as to give one of the characters to the species. Some of them have the *tubers* in pairs, hence called *didymous*, or twin (31). Some have them divided in pairs, and each of them divided into four or five fingers, hence deserving the name of *palmate* (32). Where the fleshy mass is pear-shaped, rising from the life-knot, it gets the name of a *bulb*, as in the crocus, hyacinth, and onion. The bulb may be *solid*, as that of the crocus (33), having the green bud of the leaves rising from it, and the flattened disk below it, from which the roots are hanging down, and being covered with a thin brown cuticle, which peels off in narrow strips. This root, whose solidity is shown in the cross section (34), is sometimes called a *cormus*. A *scaly* bulb has been already shown (25), which is solid too, but is distinguished by its covering of scales, which are *imbricated* or laid over one another, as indeed scales must always be. The onion is a bulb too (37), but it approaches more obviously to a stem in its structure than the other bulbs do; for, if it be cut across, it is seen to consist of many layers wrapped round one or more centres (38). Sometimes the tubers are numerous and small, and when very small, like peas, connected by stringy fibres, the root is said

Fig. 35.

Fig. 36.

Fig. 37.

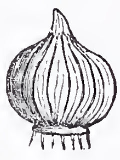
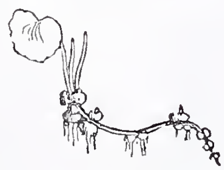


Fig. 38.

Fig. 39.



to be *granulated*, as in the Saxifrage (39). These different bulbs and tubers, however varying in their form, are all intended for the same purpose,—to serve as storehouses of nourishment during the winter, from which the new stem and leaves shall shoot up in the spring. Every one who has ever cultivated hyacinths or dahlias knows that they are taken up in the end of autumn and laid past, protected from the frost, and are planted again so soon as that enemy has disappeared in the spring. The hardier bulbs, as those of the crocuses and lilies, are able to withstand the cold, and are therefore allowed to remain in the ground.

It is curious, however, that plants of this kind increase in a twofold way. Besides their flowers and seed, they have buds springing from their solid roots. The tuber of the potato presents *eyes*, from each of which, when influenced by heat and moisture, a new bud will break out and give origin to a root and a stem. It is found in many cases that it is more advantageous to propagate a plant in this way than by the seed, the resulting young ones being much larger and stronger. Thus no one thinks of sowing potato plums, unless in the expectation of acquiring perhaps some new variety. By way of economy, a single potato is not planted whole, but is cut into several pieces first; and it must be plain, from what has been said above, that the cutter must take care to preserve one *eye* at least in each piece. Solid bulbs, as the crocus, propagate also in this way, but, having no eyes over their surface, the new one grows from the top of the old (35) from its life-knot. In this way those beautiful patches of crocuses are obtained where the various coloured flowers blow as thick as they can stand, having been multiplying by the roots for many years, with of course yearly additions from the seed which had been allowed to ripen. In the case of the scaly bulb, the new one grows from the side of the old one (36), separating some of the scales, and emerging between them, as in the case of the large white lily. In some of the plants which grow from scaly or coated bulbs, we find the buds which are placed in the angles between the stems and branches sometimes modified in a curious way. Instead of expanding into branches and leaves in the ordinary way, the rudimentary coats of which they consist, enlarge, becoming deposits of nourishment, from which growth may afterwards be supported, but in the meantime continuing in a condensed or undeveloped form. These bulbs are familiar as growing upon the orange lily (*Lilium bulbiferum*), and even among heads of flowers, as on a variety of the common onion.

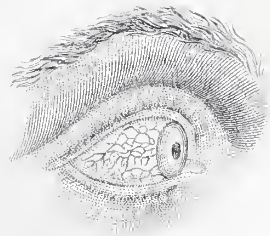
It can scarcely be necessary to say farther, that all the substance of a root which does not consist merely of the radicles, their spongioles, and the vessels belonging to them, must be intended either to give the plant a firm hold upon the earth, so as to resist the vicissitudes of the seasons; or to serve for a storehouse of nourishment, where that which was drawn from the earth is laid up, to be ready to furnish out the growth of the coming spring, before its roots have struck out, so as to attract anything of new.

Generally speaking, every part of a root has the power of throwing out new rootlets, or fibres; so that, by taking a cutting, or portion of a root, and transplanting it, new roots will strike out, and those which exist already will grow bigger; while a stem will rise above ground, and thus a new plant will be obtained. Many stems even have this power, sending out roots from the buds which would have become branches, had they remained in the air. In every garden the ranks of the gooseberry and currant bushes are supplied in this way—a slender shoot being cut from off a bush of a good kind, and stuck in the ground, where it speedily takes root, and begins to shoot out leaves and twigs.

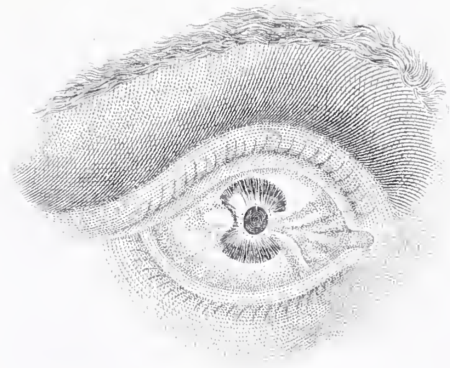
Besides the office of drawing up nourishment from the soil, it has but recently been ascertained that they have the duty of excreting, or sending off, part of the circulating fluid, which is not required, or is unsuitable for their growth. If a young growing plant be placed in a glass of water, this will be found in a few days highly impregnated by a matter excreted from the roots, and differing in different kinds of plants. It has also been found, by careful experiment, that a plant may be induced to take up a noxious substance, dissolved in the water in which it is growing; and that it will get quit of this again from its roots, when they have been washed, and placed in clean water. We may state that this curious discovery has led to an explanation of the necessity for, and advantages of, the rotation of crops, the action of what are called weeds, the utility of changing the earth of plants growing in pots, and various other phenomena which were not previously accounted for.

Roots are distinguished into annual, biennial, and perennial. Annual roots grow up, and produce leaves, flowers, and fruit, all in one season, and then wither away and perish. The barley and the poppy are examples. Biennial roots produce herbage the first season, but no flowers; the second summer they shoot out stems and flowers, run to seed, and

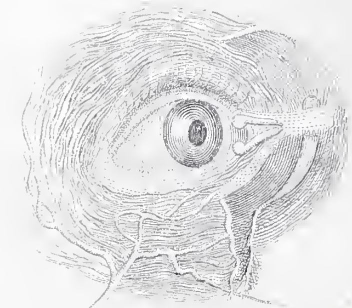
ANATOMY & PHYSIOLOGY.



NEBULA

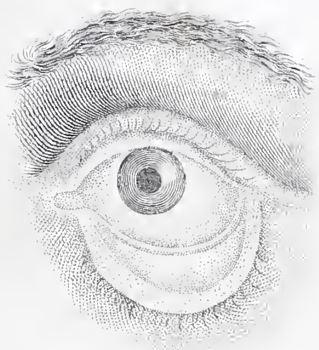


PTERYGIUM



LACHPYMAL PARTS OF EYE

Fig. 2



ECTROPIUM

Fig. 4

CURED ECTROPIUM

Fig. 2

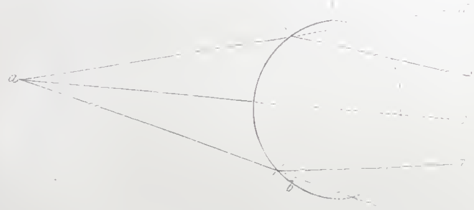
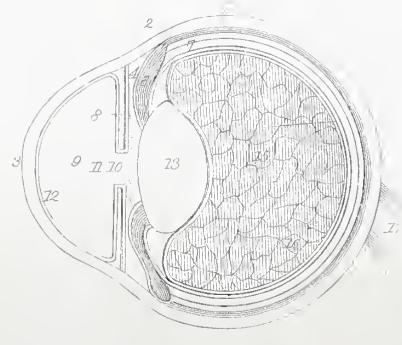


DIAGRAM OF VISION

Fig. 7



SECTION OF HUMAN EYE

Fig. 8

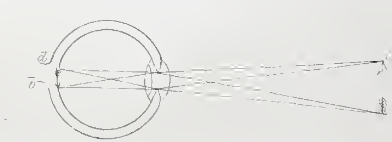
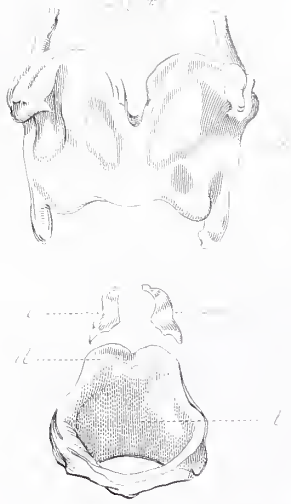


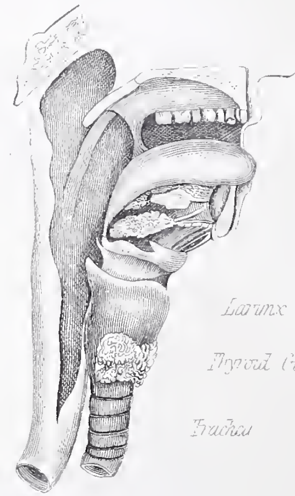
DIAGRAM OF VISION

EAR



CARTILAGES OF LAR

HUMAN TEETH



THROAT AND GULLET

A SPINAL NERVE

die away;—as the carrot, the cabbage, the foxglove. Perennial plants are those which live many successive seasons. Some of them are herbaceous, sending up stems and leaves, which flourish and fade down to the ground in one season, as the asparagus does; while the root remains, and sends up a new crop with the returning spring. Others remain entirely above ground, and are called shrubs or trees. In the botanical books, certain signs are used for these modifications;—⊙ signifying annual; ♂, biennial; ♃, perennial. Plants are sometimes changed from annual to biennial and perennial, by change of climate and cultivation.

It is only necessary farther to remark, that it is improper to perform transplantation except when the juices of the plant have retired, and it is dry, as during winter; and then the new radicles shoot out again in spring, just as if the plant had been left alone.

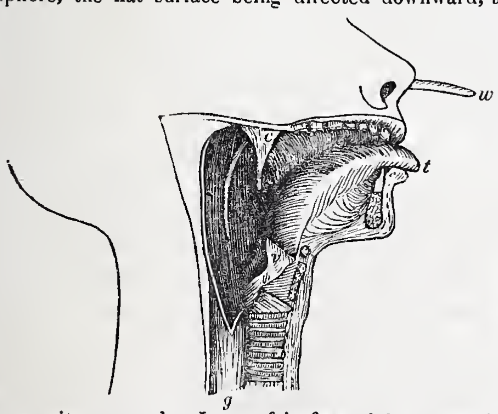
ANATOMY AND PHYSIOLOGY.

CHAPTER XVII.

OF DIGESTION.—THE MOUTH AND TEETH.

In all living bodies there is a continual waste going on which requires to be repaired by nourishing matter taken from without, and added to the system. Vegetables depend for their existence on extraneous matter, which is taken up by the roots, and distributed by means of the sap-vessels. But the grand characteristic of animals is their possessing a stomach, a central cavity into which the nourishing matter is first put, to be thence taken up into the circulation, and so distributed all over the system. The stomach and bowels constitute the proper digestive apparatus, and several other organs which co-operate in various ways to aid it, are the assistant digestive apparatus. Besides, we have a set of organs for preparing the food for the stomach, tearing, bruising, and grinding it, and mixing it with fluid, that it may be easily swallowed and digested. It is most convenient, though, perhaps, not most philosophical, to trace these parts successively from the mouth downward; we will therefore commence with the jaws, mouth, and teeth; examine the salivary glands, the palate, and the bag of the gullet; inquire into the nature of the action of swallowing, and trace the food as far as the stomach. From the stomach we will follow it down into the small intestines; see how it is mingled with the bile and the pancreatic juice; and learn how the nourishing parts of it are absorbed and carried into the circulating mass; and how that part which is useless is pushed on, until it be expelled from the body.

The *mouth* is a cavity having somewhat the shape of a hemisphere, the flat surface being directed downward, and



the convexity upward. Its roof is formed by bone; it is shut in at the sides and front by the muscular parts forming the cheeks and lips; below, it is enclosed by the lower jaw, and its floor is formed by the tongue. In the figure, the right half of the lower jaw has been removed, leaving the bag of the *pharynx* open. From the back part of the mouth hangs down the *pharynx*, a conical bag, which leads into the gullet *g*, and the nose communicates with it from above, as shown by a piece of whalebone *w*. Hence is the reason that we can breathe equally by the nose or mouth; and, that sometimes if we be taken by surprise with a fit of coughing while swallowing, the contents of the throat run out through the nose. In order to prevent this from occurring constantly, there is a curtain *c* placed at the back of the mouth, which we see on looking into a glass; and which rises or falls according to the necessity for its being applied either above or below. A long red tassel hangs down from the centre of it, nearly touching the top of the tongue, endowed with great sensibility, and warns the curtain to rise whenever the food comes in contact with it. When food is about to be swallowed, it is rolled about in the mouth and mixed with saliva, till it forms a kind of ball; and when this gets to the back of the mouth, between the arches of the palate, there is felt an irresistible tendency to swallow. The curtain now rises so as to prevent any of it passing up into the nose; the tongue rises against the roof of the mouth, so as to keep it from getting forward again; and the only course left for it is to pass down into the gullet, pushing down the valve *v* of the windpipe as it passes. It is a mistake, however, to suppose that food *falls* into the stomach, the fact being that a man can swallow nearly as well when standing on his head as on his feet. This will be understood if we suppose an imaginary division of the gullet into a number of rings. When one ring contracts, the food passes on into the next; then the second contracts, and squeezes it down into the third; while the first being still contracted, prevents it from getting up; and so the process goes on, regularly downward, until the ball arrives at the stomach. And in vomiting, an action precisely the reverse of this takes place, and the food is *squeezed up* from the stomach into the mouth, although so rapidly that its passage seems almost instantaneous.

The *tongue* is fixed to the back of the chin, and has a muscle arising from this point, and radiating through it, forward, upward, and backward; so that it can protrude the tongue, turn it upward, downward, or to the side, render its surface convex or hollow, to serve for a conduit, as in drinking. There are three pairs of muscles actually forming the substance of the tongue, and not less than six pairs more which can aid in its motions. The whole inner surface of the mouth is lined with a soft mucous membrane, so called because it pours out a mucus from its surface to lubricate it, to protect it, and to assist the food to slide easily through it. The upper surface of the tongue is studded with many delicate *papillæ* or points, in which the nerves of taste end, which vary in appearance in different animals. In the cow, for example, they are much rougher than in man; in the lion they are so rough as to be capable of peeling one's skin off, should he attempt to lick it; and in some of the marine animals which swallow living shell-fish, both the tongue and the gullet are covered with thickly set spines, directed backward, to prevent their prey from actually creeping up again.

Six *glands* are placed about the mouth for the purpose of supplying *saliva* to be mixed with the food. Two very large ones lie behind the ear, in the hollow between the lower jaw and the temporal bone, so that the motion of eating squeezes out their contents. Their *ducts* run forward in the cheek, and perforate the mouth opposite the second last tooth in the upper jaw, where, with the tongue, a small soft projection may be recognised. Two others lie on each side under the tongue, having a common duct, which may be seen opening on the fold of the membrane that bridles down the tongue. This fold, by the by, it may be mentioned here, is what produces the appearance called *tongue-tacked* when too short. The tongue cannot then be put out of the mouth, and the infant cannot suck until the fold be divided by a pair of scissors. This little operation, trifling though it be, should never be intrusted to any one but the attending surgeon; for there are a couple of arteries lying close to this bridle, which are apt to be divided by an ill-directed incision. The tonsil is

seen in the last figure, just beyond the little tassel; it is of the size and shape of an almond, secreting mucus to moisten the throat from many little pits on its surface. It is this which inflames, when one is said to have a sore throat. Sometimes it enlarges so much as to interfere with breathing; and then it requires to be removed.

One or other of the ducts which open below the tongue is subject to become stopped up, and the saliva distends it into a soft swelling, which impedes the motions of the tongue in the actions of speech and mastication, and requires to be punctured. Sometimes the saline constituents of the saliva concrete into a stone, which requires to be cut out. But the most annoying thing connected with the salivary duct is, when one of those running in the cheek is divided, as by a sabre cut; it is then scarcely to be got to heal, and the saliva is constantly running over the cheek. The quantity which is lost in this way, in such a case, in the course of a day, is surprisingly great.

The *teeth* are the hardest parts of the whole body. In the adult they are thirty-two in number, eight upon each side of each jaw. They are of four different kinds. In front there are, on each side, two incisors or cutting teeth, whose edges are like that of a chisel; next there is one eye-tooth, which is pointed; thirdly, there are two small grinders; and lastly, there are three large grinders. The teeth in the two jaws do not exactly meet; the cutting teeth of the upper jaw overlapping those of the under, while the grinders just face one another. We sometimes, however, see people whose under teeth project beyond their upper, giving a peculiar appearance of length to the lower part of the face.

In the figure a grinding tooth is represented, sawn through perpendicularly. We describe three portions of the tooth, the *crown* being that part which appears above the gum, the *body* the thick part, and the *fangs*, or roots, penetrating down into the socket. A cavity is seen in the body of the tooth, occupied by a pulpy substance, containing some bloodvessels and nerves; and a small canal is seen leading from the cavity into each fang, and opening by a minute hole, through which the bloodvessels and nerves enter.

The bony part of the tooth which projects above the jaw, and is destined to meet its fellow, and to come in contact with the fluids in the mouth, is protected by the *enamel*, which is the hardest substance in the body. It is thought not to be an organized substance at all, as neither blood nor sensibility has been detected in it; so that it seems to be merely a protection, to prevent the remainder of the tooth from being worn. When broken off, it is never replaced, and the tooth of necessity passes into decay.

The structure of the bony part of the tooth is similar to that of bone elsewhere, only it is much harder. Hence, by referring to the chemical structure of bone, (Chapter IV.,) it will be understood how the teeth are pained when anything sour is taken into the mouth; why the patient who is to use acid drops is always directed to suck them through a quill, that they may not come in contact with the teeth; and how the teeth blacken, and are actually dissolved away, in persons who are subject to acidity of the stomach. When a hole has formed in a tooth, no pain is felt until the cavity be reached and the nerve exposed, and then, as almost every one knows by experience, the pain is most excruciating. Sometimes it is relieved by some powerful stimulant dropped into the tooth, as the essential oil of cloves,—sometimes by the recently discovered substance called *creosote*, which has the property of deadening the nerve,—and sometimes the tortured victim is glad to appease the tormentor by actually destroying the nerve, by the introduction of a hot wire. If the cavity be not large, it ought to be stopped, an operation which generally succeeds in preserving the tooth for a long time, by excluding the air and all other agents which could act upon it. This stopping ought to be done with gold leaf, and by a respectable dentist; and no one should trust his teeth to the hands of the advertising charlatans, whose object, to secure constant employment to themselves, is not to preserve, but to destroy. If stopping the tooth be not successful in preventing the recurrence of toothache, the offending member must be removed; and this last resource should never be deferred so long that the stump requires to be dug out of the jaw; because then, what is a brief though painful operation, is converted into one which is tedious, and often insufferable.

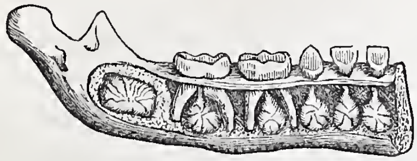
The teeth at first lie deep within the jaw-bones, and are covered at birth by the thick gum. Their rudiments at birth are very small. The crown or upper part of the tooth is formed first, then the body, then the enamel is deposited on the crown, and lastly, the fangs grow as the tooth becomes protruded. When the jaw of a new-born child is dissected, a pulp is found for each tooth, like a little stool, into which bloodvessels are seen running, on the top of which the bone is deposited; and after the tooth has attained its shape, the pulpy stool shrinks away almost to nothing, except the small quantity of cellular tissue which conveys the vessels and nerves into the central cavity.

The whole tooth is enclosed within a delicate membrane, which becomes ruptured when the tooth bursts forth. The gum of an infant has a sharp line running along it, which serves it to catch anything that is put into its mouth; and this line becomes broader and flattened, and finally disappears, previous to the eruption of the teeth. The order of eruption is generally the following:—First, the two central incisors of the lower jaw appear, then the corresponding ones above; next, the lateral ones below, then the corresponding ones above. After this, the order is not regularly backwards, for the foremost of the two grinders now appear below, then those above, then the eyeteeth below, then the corresponding ones above, and lastly, the second grinders come through about the end of the second, or beginning of the third year. When they do not follow this order, dentition is generally attended with more than usual irritation.

The period when the teeth appear varies very much. The author knows one lady who was born with teeth, and has seen a child born with a couple, and every one knows what Richard III. says of himself on this subject. It is rather early for them to appear at the age of four months; more commonly seven have passed before any signs of uneasiness are manifested, and sometimes even twelve or thirteen. A good deal of constitutional disturbance generally attends teething: the mouth is hot, the gums itchy, and the infant rubs them with anything it can get into its hands. For this purpose nothing is so good as the common ivory ring; all manner of corals and bells should be discarded, as they are apt to injure the mouth, or even to be thrust into the eyes. The bowels are apt to become deranged, and require constant attention. But nothing does the infant so much good as scarifying its gums. It is quite a mistake to suppose that this trifling operation gives pain; on the contrary, it is a source of instantaneous relief, and should be resorted to as often as the child manifests any signs of uneasiness. When this is neglected, teething is apt to bring on bowel-complaints, convulsions, and even that most intractable of diseases, water in the head.

From the hardness of the teeth, they are not capable of growing, so as to fill up the increased size of the jaws in after years. Hence we see a growing child come to have spaces left between its teeth, as they are removed from one another by the elongation of the jaw. About the end of the seventh, or beginning of the eighth year, a third grinder on each side of each jaw makes its appearance, which is the first permanent tooth, and never changes. When this one is rising above the gums, the central incisors of the under jaw are becoming loose. If a jaw-bone be dissected at this period, and its outer part be filed away, a very beautiful preparation is obtained. The first teeth are seen in their places, and the second set are seen deep in the jaw, below, and rather behind them, ready to rise up and supplant them. (The figure represents the right half of the lower jaw, containing the five milk teeth, and filed away so as to display the bags in which the second set are contained.) It is, however, quite

a mistake to suppose that the new teeth push out the old; the fact is, that they cannot get up until the old ones be removed.



Preparatory to the removal of the old ones, their fangs become absorbed, so that they are not a quarter of an inch in length; whereas, had they been examined some months sooner, they would have been found three times as long.

Some time between the completion of the seventh and eighth year, the second dentition commences. The first permanent grinders appear, and the central incisors fall out and are replaced. In three months more, the lateral incisors follow. In from six to twelve months more, the grinders give way, and after them the eye-teeth. The grinders are succeeded by a new species of teeth, which do not exist in the milk set, called the small grinders. These changes take place about the tenth or eleventh year, and it is not for two or three years more that the second of the permanent grinders makes its appearance. A long interval now succeeds, and the jaw acquires its full proportion, and about the ninteenth or twentieth year the wisdom-tooth cuts the gum, but sometimes not till even a later period. The author has met two instances of persons getting their wisdom-teeth at the age of thirty, and in one of these they were quite decayed before they had actually become visible. The grinders often give a good deal of pain in coming through, on account of their broad surfaces meeting with much resistance, and much relief is obtained by having the gum freely scarified.

MATHEMATICS.

CHAPTER XIII.

RULE OF THREE.

Definition I.—When two magnitudes are compared with each other by finding the number of times that the one is contained in the other, that is, by dividing one of them by the other, the resulting quotient is called their *ratio*. Thus 3 is the ratio of 12 to 4, since 3 is the quotient of 12 divided by 4, and which is usually indicated by writing 12 : 4. It is manifestly indifferent, however, in this mode of comparison, whether we say that the first of the numbers (12) is triple of the second (4) or that the latter is a third of the former; hence we might, with equal correctness, call $\frac{1}{3}$ the ratio of 12 to 4. In this we only suppose the order of division or comparison to be changed, and instead of considering 12 : 4, we take the quantity in the order 4 : 12, supposing that we make it a general rule to divide the first of the numbers enunciated by the second.

Definition II.—When the ratio of two numbers is the same with that of two others, these four quantities form a *proportion*, which results from the equality of two ratios. Thus, the ratio of 15 to 5, and of 18 to 6 is 3; and, accordingly, these numbers constitute a proportion which we write as follows:—

$$15 : 5 :: 18 : 6, \text{ or } \tfrac{15}{5} = \tfrac{18}{6}.$$

We commonly make use of the first of these forms of expression, although the last is in some respects the most convenient. The meaning given by both forms of the notation is, that the quotient of 15 divided by 5, is equal to the quotient of 18 divided by 6, that is, the ratio of 15 to 5, is equal to the ratio of 18 to 6. But the formula of enunciation is this:—as 15 is to 5, so is 18 to 6; or, more shortly, 15 is to 5 as 18 is to 6. All these forms of expression are equivalent.

The four numbers being proportioned in the order written, the terms 15 and 6 are called the *extremes*, and 5 and 18 the *means* of the proportion; and since $\frac{15}{5} = \frac{18}{6}$, it follows from the nature of fractions, that $15 \times 6 = 5 \times 18$; that is, the product of the extremes is equal to the product of the means. It is also obvious, from the same principle, that we may multiply or divide the pairs of terms 15 and 5, and 18 and 6 by any numbers, without destroying the equality of their ratios. Thus, multiplying the first pair by 2, and dividing the second pair by 3, we obtain the proportion 30 : 10 :: 6 : 2, the common ratio of which is 3 as before. The product of the extremes is likewise still equal to the product of the means, and this condition being maintained, the proportion is not destroyed.

From this condition of equality of the products of the extremes and means, it immediately follows that the fourth term of the proportion must be equal to the quotient resulting from the division of the product of the means divided by the first term. Thus, taking the last proportion stated, the product of the means is 10×6, or 60, and the quotient of 60 by 30 the first term, is 2 the last term. From this, it follows that, if the last term of a proportion be wanting, it may be found by a process of multiplication and division; and this process, simple as it is, constitutes the extensive rule in commercial arithmetic, popularly denominated the Rule of Three, because in it three quantities are given, and a fourth is required to be found. As an illustration let us take the following question:—

An engineer having finished 100 yards of work in a certain number of days, with 5 men, how many yards may he finish of a like quality of work in the same time with 8 men?

Here, it must be observed, that there are two quantities of the same sort, namely, 5 men and 8 men; and a third of another sort, namely, 100 yards, but the answer required by the question is of the same nature as this last, namely, yards. Let therefore this number of yards be in the meantime denoted by x. Then, in order that these four terms may constitute a proportion, the ratios of the pairs must be equal to each other,—that is,

$$\overset{\text{men.}}{5} : \overset{\text{men.}}{8} :: \overset{\text{yards.}}{100} : \overset{\text{yards}}{x}.$$

But, regarding the numbers expressing these quantities as abstract, then the value of x is found, as explained above, by dividing the product of the two means by the first term,—that is,

$$x = \frac{8 \times 100}{5} = 160.$$

The quantity x is therefore equal to 160 yards, the fourth term of the proportion, which will now stand as follows:—

$$\overset{\text{men.}}{5} : \overset{\text{men.}}{8} :: \overset{\text{yards.}}{100} : \overset{\text{yards}}{160},$$

and the proof that this proportion is correct is, that the product of the extremes is equal to the product of the means.

From this we may infer that the sole difficulty of solving questions by this rule consists in placing the numbers contained in the question in their proper order in the proportion; and this depends upon a correct interpretation of the conditions stated. The process of reasoning is, however, very simple. In the first place, we ascertain, from the nature of the question, whether the solution depends upon a proportion; and this is the case when it has two terms of the same kind, which may be either multiplied or divided by the same number, without making any change in the nature of the problem;* and a third quantity, which is of the same kind as the answer sought. We next consider whether the answer ought to be a greater or less quantity than the *odd* term; that is, whether the unknown term, which is to be found, ought to be greater or less than that of the same sort which is given; and from this we determine which of the two given terms of the same kind ought to be placed first in the proportion—the least being placed first, as the divisor, when the answer ought to be greater than its corresponding term; and *vice versâ*. Thus, in the preceding question, having set down 100 yards : x yards, we see that 8 men must, of course, do more work than 5 men; consequently, x must be greater than 100; and hence, of the two numbers, 8 and 5, the last must be placed first, as above. The following two questions will serve further to illustrate this:—

A piece of work can be done in 5 days by 57 men: in how many days ought the same to be completed by 19 men? This is manifestly a question of proportion; since we might take two or three times as many days, and as many times fewer workmen,

* It may happen that a problem has two terms of the same nature, or, as mathematicians express it, two homogeneous terms; and yet not admit of multiplication or division by the same number, without changing the conditions of the question. Thus, the time of a stone's falling to the ground is not doubled when the height is doubled; and a vessel of water is not three times longer in emptying itself when its capacity is triple. Elements of that nature, although homogeneous, cannot therefore enter as terms of a rule-of-three questiou.

without any change in the problem. Again our odd term is 5 days, and the answer sought is x days; and since a greater number of days must obviously be allowed to 19 men than to 57 men, to accomplish the same amount of work, it follows that x is greater than 5; and consequently, of the two numbers, 19 and 57, the former is the first term of the proportion. The statement is, therefore, as follows:—

$$\overset{\text{men.}}{19} : \overset{\text{men.}}{57} :: \overset{\text{days.}}{5} : \overset{\text{days.}}{x} = \frac{5 \times 57}{19} = 15$$

Six yards of cloth, $\frac{3}{4}$ wide, were required for a certain purpose; how many yards are necessary, the width being $\frac{2}{3}$? Although in this question the four terms are all yards, we see that in one case they represent length, and in the other breadth; and that 6 yards and the unknown quantity are of the same kind—namely, length. The second pair of terms of the proportion is, therefore, 6 yds. : x yds. Also, the broader the cloth, the less must be the length necessary; and $\frac{3}{4}$ being greater than $\frac{2}{3}$, we must find x greater than 6. Consequently, $\frac{2}{3}$ must be the first term, and $\frac{3}{4}$ the second of the proportion; thus, $\frac{2}{3} : \frac{3}{4} :: 6 : x$. But as the first ratio will not be changed by multiplying its terms by the same number, we may get rid of the fractional form in which these terms are expressed, by multiplying them by a multiple of their denominators; that is, by 3×4, or 12. This multiplication being performed, the proportion becomes

$$8 : 9 :: 6 : x, \text{ when } x = \frac{9 \times 6}{8} = 6\tfrac{3}{4}$$

That is, $6\frac{3}{4}$ yards of cloth, of $\frac{2}{3}$ yd. wide, are equivalent to 6 yards of $\frac{3}{4}$ yd. wide.

It often happens, especially in commercial questions, that the terms given consist of various denominations. This has the effect of rendering the calculation more lengthy; but it in no way affects the principle. Thus, suppose we have this question:—What is the price of 18 yds. 2 qrs. 2 nails of cloth, at the rate of 3 yds. 2 qrs. for £1 16s.?

Here the term sought is money, the corresponding term being £1 16s.; and since 18 yds. 2 qrs. 2 nails will cost more than 3 yds. 2 qrs., we make the least of these quantities the first term. The statement is, therefore, this:—

3 yds. 2 qrs. : 18 yds. 2 qrs. 2 nls. : : £1 16s. : £x.

But as we cannot multiply and divide by the first terms in their compound state, and as they admit of multiplication without affecting the question, we reduce them both to the same denomination; namely, *nails*. We also reduce the third term to the lowest name contained in it; namely, *shillings*. The statement, thus modified, is as follows:—

56 nails : 298 nails : : 36 shillings : x shillings.

We might now proceed to multiply 36 shillings by 298, and to divide the product by 56; by which we would find the value of $x = 191\frac{32}{56}$ shillings. But, observing that the first and second terms are both divisible by 2, we perform that operation, which does not affect the ratio; and the statement is reduced to the following:—

28 nails : 149 nails : : 36 shillings : x shillings.

We might solve the question also with these numbers, from which we would find $x = 191\frac{16}{28}$ shillings as before; but, since the first term is a divisor, and the third a multiplier, it will evidently not affect the value of x; that is, the answer sought, to divide these terms by 4, and, this done, the proportions is as follows,

7 nails : 149 nails : : 9 shillings : x shillings,

and this is not suceptible of further reduction without introducing fractions. To find x then, we have

$$x \text{ shillings} = \frac{9 \text{ shillings} \times 149}{7} = 191\tfrac{4}{7} \text{ shillings} = £9\ 11\text{s. } 6\tfrac{3}{4}\text{d. } \tfrac{3}{7}$$

The compound quantities in this question might have been converted into fractions, and the operations performed by the rules for multiplying and dividing fractions, thus,

$$\overset{\text{yards.}}{3\tfrac{1}{2}} = \tfrac{7}{2} : \overset{\text{yards.}}{18\tfrac{5}{8}} = \tfrac{149}{8} :: £1\tfrac{4}{5} = £\tfrac{9}{5} : £x,$$

$$\text{whence } x = £\frac{9 \times 149 \times 2}{7 \times 8 \times 5} = £\frac{2682}{280} = £9\ 11\text{s. } 6\tfrac{3}{4}\text{d. } \tfrac{3}{7}$$

Or the quantities might have been converted into decimals, and the operations performed by the rules for decimals, thus,

3·5 yds. : 18·625 yds. : : £1·8 : £x,

and, dividing the first two terms by 5, this becomes

·7 yds. : 3·725 yds, : : £1·8 : £x

$$\text{whence } x = £\frac{1{\cdot}8 \times 3{\cdot}725}{{\cdot}7} = £\frac{6{\cdot}705}{{\cdot}7} = £9\ 11\text{s. } 6\tfrac{3}{4}\text{d. } {\cdot}42857\ldots$$

From the preceding operations it then appears that the first and second terms must be of the same kind and denomination, and that the third term may be reduced to any denomination which may be the most convenient; observing that the answer will be a quantity of the same name. The first and second terms, and also the first and third terms may be multiplied or divided by any number without affecting the answer—which allows of the terms being reduced, and the operation abridged or made more convenient. No precise rule, however, can be given for the performance of these modifications; and it depends entirely upon the ingenuity of the student, to detect when they are applicable, and to what extent.

Sometimes the proportion appears deficient in the number of its terms, as in the following question:—

A ship's crew have provisions left for 10 days' rations, but wish to remain at sea for 15 days; to what must each ration be reduced? Here we do not find four terms; but it is evident that one of them is understood, and that the problem is equivalent to the following:—The ration 1 would be given to each man were they to remain at sea 10 days; but, as they are to be at sea 15 days, what fraction of the ration 1 should be allowed him? The statement is obviously $15 : 10 :: 1 : x = \frac{2}{3}$.

Similarly—If a reservoir be filled by one pipe in 6 hours, by another in $5\frac{1}{4}$ hours, and by a third in $4\frac{2}{3}$ hours; in what time will it be filled by the three pipes all running together? The first consideration here is the portion of the reservoir which is filled by the first pipe in 1 hour, that is this question: If the whole be filled in 6 hours, what part will be filled in 1 hour? In answer, we have 6 hrs. : 1 hr. : : 1 : $x = \frac{1}{6}$. And similarly for the other two, we have

$5\frac{1}{4}$ hr. : 1 hr. : : 1 : $x = \frac{4}{21}$; $4\frac{2}{3}$ hr. : 1 hr. : : 1 : $x = \frac{3}{14}$.

Thus, the three pipes running together will in 1 hour fill this fraction of the reservoir, viz., $\frac{1}{6} + \frac{4}{21} + \frac{3}{14}$, that is, $\frac{7}{42} + \frac{8}{42} + \frac{9}{42} = \frac{4}{7}$; and the question now becomes: If $\frac{4}{7}$ of the reservoir be filled in 1 hour, in what time will the whole be filled? It will evidently require more than 1 hour: the proportion is therefore as follows,

$\frac{4}{7}$ (of cap. of reservoir) : 1 (whole cap. of reservoir) : : 1 hr. : x hr.

whence $x = 1 \text{ hr.} \div \frac{4}{7} = 1 \text{ hr.} \times \frac{7}{4} = \frac{7}{4} \text{ hr.} = 1\frac{3}{4}$ hr.; that is, the three pipes will, when all running together, fill the reservoir in $1\frac{3}{4}$ hour.

Questions of this kind may, however, be resolved independently of the rule of three: thus unity (1) being divided by the times in which the reservoir would be filled by each of the pipes separately, gives the fractions of it which they would severally fill in the given unit of time; and that unit, being divided by the sum of the fractions of the whole capacity thus filled, gives the whole time. For instance, in the question above, the times are 6 hours, $5\frac{1}{4}$ hours, and $4\frac{2}{3}$ hours, and 1 divided by each of these quantities gives the fractions $\frac{1}{6}$, $\frac{4}{21}$, $\frac{3}{14}$, the sum of which, as found above, is $\frac{4}{7}$; and 1 hour, divided by $\frac{4}{7}$, gives $1\frac{3}{4}$ hour as before.

It frequently happens that questions contain more than three given quantities. When these consist of two periods in which the terms are respectively of the same kind, and vary proportionally, the question constitutes what is termed a *compound proportion*, and its solution belongs to the Double Rule of Three. The following is an example:—

If 20 men can build 160 yards of wall in 15 days, how many yards ought 30 men to build in 12 days? Here the 20 men and 15 days may be regarded as associated agencies in producing the effect expressed by 160 yards, and 30 men and 12 days in producing the effect x yards to be found; but the efficiency of 20 men working 15 days may be expressed by 20×15 or 300 and the efficiency of 30 men working 12 days by 30×12 or 360. Now as 160 yards is the effect produced by 300, it is obvious that x must be greater than 160 yards, since the agency to effect

it is expressed by 360. In other words, we have this simple proportion:

$$300 : 360 :: 160 \text{ yards} : x = 192 \text{ yards}.$$

This statement might of course be abridged to 1 : 12 : : 16 yards which also gives $x = 192$ yards.

Similar reasoning may be employed in every other case, as in the following rather complicated example.

If 30 men in 40 hours can dig 80 cubic yards, how many yards will 80 men, stronger in the ratio of 5 to 4, dig in 90 hours, supposing the ground in this case harder in the ratio of 9 to 8? Here 80 cubic yards are dug by a force which may be expressed by 30×40 or 1200, and the force to be employed in digging x cubic yards is $80 \times 90 \times \frac{5}{4}$ or 9000; but the ground is in this case harder in the ratio of 9 to 8, consequently the efficiency of the units of force in 9000, as compared with the efficiency of the units of force in 1200, will be diminished in respect to x in the ratio of 8 to 9; that is, the force 9000 applied to work more difficult in the ratio of 9 to 8, will be in effect reduced to $9000 \times \frac{8}{9}$ or 8000. The quantities 1200 and 8000 being thus reduced to units of the same kind, it is clear that 8000 must be equivalent to a greater effect than 1200, that is, x must be greater than 80 cubic yards. The proportion is therefore the following:—

$$12{,}00 : 80{,}00 :: 80 \text{ cubic yards} : x = 533\tfrac{1}{3} \text{ cubic yards}.$$

This species of reasoning is applicable to all questions of this class, and is easily applied in practice; but perhaps the readiest mode of proceeding is the following: draw a horizontal line, and above it on the right place the term which is of the same kind as that sought. This, in the question just discussed, is 80 cubic yards. Next take a pair of like terms, as 30 men and 80 men, and consider with regard to *them* whether the answer ought to be greater or less than 80 cubic yards; if greater, place the greater term above the line and the less beneath, and *vice versâ*. In this case, as 80 can do more work than 30 men, the answer ought to be greater than 80 cubic yards: hence 80 is placed above and 30 below the line. The answer in like manner ought to be greater in respect to the time, and hence 90 hours is placed above and 40 beneath the line. The ratio of strength of the 80 men also indicates a greater answer than 80 cubic yards, and hence the 5 is placed above and the 4 below; but the ratio of hardness on the contrary indicates a less answer, and hence the 9 is placed below and the 8 above the line. The statement of the question, the sign of multiplication being inserted between the terms, is now complete, and the terms may be considered as those of a fraction of which it only remains to find the value, which is of the same nature as the odd term. The terms above and below the line may however have all their common factors struck out before the reduction is commenced, to simplify the operation. The statement above will by that means be reduced to the following:—

$$\frac{8 \times 5 \times 90 \times 80 \times 80 \text{ c. yds.}}{9 \times 4 \times 40 \times 30}$$

$$\frac{2 \times 5 \times 1 \times 2 \times 80 \text{ c. yds.}}{1 \times 1 \times 1 \times 3} = \frac{1600 \text{ c. yd.}}{3} = 533\tfrac{1}{3} \text{ c. yd.}$$

as found by the former process. The same mode may be followed with any other question of this nature, however numerous its terms may be. We may give the following question as an exercise upon the rule:—

If 40 men can complete 300 yards of work in 8 days, working 7 hours a-day; in how many days will 51 men finish 459 yards working 6 hours a-day? Ans. 11·2.

In some other treatises on arithmetic, the student will find what are called *direct* and *inverse* rules-of-three with suitable examples and exercises; we have only to caution him against giving heed to any such futile distinctions. Should he understand the subject thoroughly, as explained in the foregoing article, he will find little difficulty in solving any rule of three question which may come before him. There are, however, still some peculiar cases of the application of the rule, to which we intend to return.

IRON-FOUNDING.

SECTION V.

FURNACES.

The process of melting pig-iron preparatory to its being cast in moulds, constitutes one very important branch of the economics of the art of iron-founding. Various efforts have been made towards the perfection of this process, with the view not only of preserving the quantity and quality of the iron, but also of reducing the expense of the process. It is only of late, however, that distinct ideas seem to have been formed upon the subject, as will appear in the following account of the past and present condition of the system of iron melting adopted by founders.

Furnaces in which iron is now usually melted for the purposes of casting, are usually denominated *cupolas*, derived, we believe, from the *cupella* of the chemists. Previous to their introduction in founderies, *air-furnaces* were always employed for the fusion of metal. The principal distinction between these two kinds of furnace, is to be found in two circumstances: the fusion of metal in air-furnaces is urged by the natural draft due to the height of their chimneys, while cupola furnaces, on the other hand, depend for their efficiency upon an artificial blast of air. On these accounts, coal is the appropriate fuel for the former kind of furnace, and coke, a preparation of coal to be afterwards described, is employed in the latter furnace. Again, in the air-furnace, the fuel is never allowed to be in contact with the charges of iron, situated as the materials are at the opposite extremities of the hearth; in the cupola, on the other hand, the metal and the fuel are deposited in alternate layers upon each other, and thus become intimately blended in the course of the fusion and descent of the iron to the hearth.

Figs. 1 and 2 are vertical sections, taken at right angles to each other, of a reverberatory air-furnace. A is the fire-place, and B, the ash-pit. The flame from the fuel plays along the hearth C, upon which the pig-iron to be melted is deposited. This hearth is considerably inclined from the fire-place towards

Fig. 1.

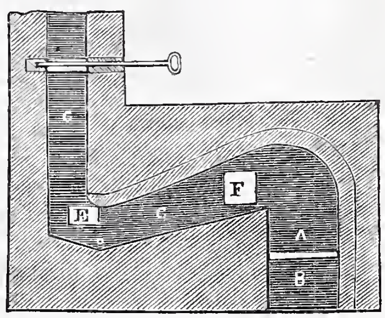
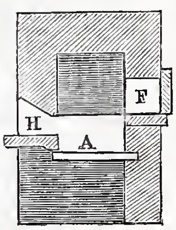


Fig. 2.



the bottom of the chimney at D, whence it rises to the opposite side. A tapping-hole is formed at D, the lowest level, by which the melted metal may be drawn off when wanted in large quantities; E is a large opening in the end, closed when not used. By this aperture, quantities of metal are lifted in by hand-ladles. G is the chimney, and H, the furnace door. Air-furnaces are now employed only for the execution of very large castings, as they are capable of supplying a very heavy draft of metal at once, beyond the capabilities of cupolas in general. But when the capacity of the cupola is sufficient to meet the exigencies of the founder, it is preferred; as the expense of melting metal by it is much below that occasioned by the air-furnace. And for the same reason, in many cases it is usual to melt the metal for a large casting in the cupola by successive portions, and to draw it off as it accumulates at the bottom, and convey it into the air-furnace by the opening at E.

When the air-furnace is to be used, it must first of all be heated up to fit it for receiving the metal from the cupola. Advantage is at the same time taken of the heat to melt a quantity of iron in the furnace. By this means a great amount of heat is put to use, which would otherwise be lost. When the furnace

is charged with iron at the commencement, it is said to be charged *cold*. If it be charged when heated up, it is charged *hot*. The following are the dimensions of an ordinary furnace of this kind: the fire-grate is 4 feet 6 inches square ; the horizontal length of hearth, 13 feet ; the perpendicular height of the roof from the hearth is 15 inches. For a 16 ton cast this furnace consumes a gross amount of $3\frac{1}{2}$ waggons of coal, at 24 cwt. a waggon ; 6 tons of iron are charged cold ; the furnace is thoroughly heated and the metal melted in 4 hours. The pigs are not extended across the hearth above one another, but are set on end, bearing against the walls of the furnace, to be as much as possible exposed to the action of the flame. The iron as it is melted,

Fig. 3.

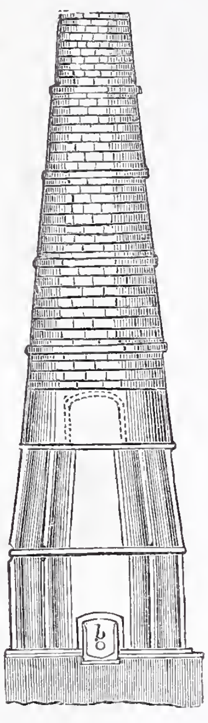
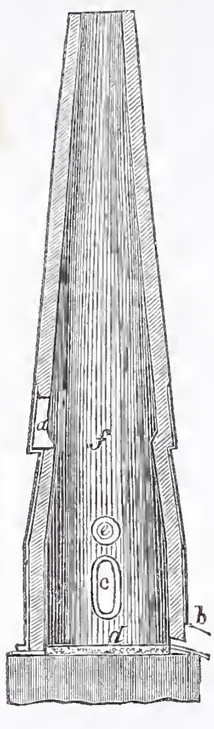


Fig 4.



runs down the hearth of the furnace to the bottom, where it is collected. The cupola metal, which has been prepared in the mean time, is next poured into the furnace by the opening at E, by means of ladles. In about six hours, the charge is ready for casting, to effect which it is simply run off at the opening D, along a channel made in the sand to the moulding.

When cupolas were first introduced into founderies, they were recommended not only by the great reduction experienced in the expense of fuel, but also by the smooth finished appearance of the surface of castings supplied by them. Though the softness of these castings was on their first introduction much complained of, yet by improved methods of management, the objection was done away. The first cupola erected in Glasgow was built in 1802, and wrought by Fulton, an iron founder in that city. It was cylindrical in the interior of the trunk or working part, the dimensions of which were sixteen inches diameter, by six or seven feet deep between the hearth and the sill of the charging-door. This cupola was no doubt of a large size at the time of erection, at least if we may judge from the importance which was then attached to the execution of a casting of two or three cwt. of cupola metal. It was well adapted by its form to work economically, on account of its parallelism of section vertically, and its remarkable depth over the tweres—remarkable if we consider that cupola furnaces afterwards erected, were made comparatively shallow, as well as contracted towards the charging door, to their disadvantage. The construction of the original cupolas was of a simple nature : a cast-iron plate bedded upon a stone foundation, supported a cast-iron cylinder about six inches wider than the finished diameter of the furnace. This, being surmounted by another plate, supported a short brick chimney. The hearth having been prepared by a smooth bed of sand laid in the bottom of the furnace, an exact pattern of its interior form was set concentrically within the casing, and fixed there till it was rammed about with sand of an adhesive and fire-resisting quality. The pattern made in segments was then extracted, and left its form upon the interior of the furnace : the same process was renewed when necessary.

Fig. 3, is a front elevation of an ordinary cupola of a large size ; fig. 4, is a vertical section in a plane at right angles to that of fig. 3 ; fig. 5 is a horizontal section at the tweres ; *a* is the charging door, about two feet square, by which the pig-iron and coke are introduced into the furnace ; *b* is the tapping hole, fifteen inches square, at which the melted metal is occasionally drawn from the furnace ; *c e*, not seen in fig. 3, are the twere holes or apertures by which the blast enters, to afford a supply of air capable of maintaining a sufficiently intense heat in the furnace by combination with the fuel. These apertures are of considerable extent upwards, so as to admit of the tweres being set to any height required, which is regulated by the quantity of metal that may be collected in the furnace ; for, of course the tweres must always deliver their air clear of the surface of the metal. The tweres are knee-pipes for delivering the blast into the cupola, into which one end is directed, while the other end slides in an upright pipe through which the blast is conveyed, in the manner of a telescope-tube, so that the twere may be set to any height required. The under part *d f*, of the structure below the charging door, is the most essential division, and is indeed that which gives its character to the furnace. The upper portion *f g*, is the chimney, intended to convey away the volatile noxious products of the whole operation of fusion, being sufficiently long to pass out through the roof of the foundery. The furnace is built entirely of fire-brick, and it will be observed that the trunk is incased in cast-iron plates bolted together. The casing is in some instances cast in one or two entire cylindrical pieces, and in other instances it is made of boiler plates rivetted together. The latter is undoubtedly the more durable material, as it stands the alternate expansion and contraction with much less injury to itself. The chimney is simply bound with wrought-iron belts fastened round it at regular intervals. The whole structure stands upon a square-base plate, of which the centre is cut out into a circular aperture ; this plate is bedded upon a brick or stone foundation represented in the figures. As the bottom must be protected from the action of the melted metal which collects there, it is laid over with a bed of sand, mixed with wet loam to give it consistency. This is shown in section at *d*, fig. 4. It is continued over the bottom and sides of the spout *b*.

A few pieces of firewood are first laid upon the hearth *d*, and covered with a body of coke sufficient to heat the furnace, while burning, into a proper state for the work, and to melt the first charge of iron ; the coke ought at all events to be in sufficient quantity to rise above the level of the tweres, so that when kindled by the fire which is lit at *b*, it may be acted on with effect by the blast which is set on in a quarter or half an hour after. The flame issues then by the orifice *b*, which has been left open on purpose to consolidate the wet loam-work by the heat. In a quarter of an hour or so afterwards, the tapping hole *b* is closed with a lump of moist clay; and sometimes when the furnace is to contain a great body of melted metal before being drawn, the clay is supported by means of a small plate of cast iron fixed against the furnace. A few minutes after the blast has been set in action, when the coke sinks in the furnace, falling into a semi-congealed condition, alternate charges of coke and pig-iron are thrown in. The metal begins to melt in from ten to twenty minutes after its introduction, and successive charges are then made at intervals of about ten minutes ; though these intervals will vary with the rapidity of melting. In setting the tweres, their nozzles are projected a little way into the holes in the furnace intended for them, and the open interstices are filled up and smoothed over with wet loam, preventing thus the escape of any of the blast.

A small quantity of limestone is usually introduced into the cupola after the first charge of metal. It is intended to act as a flux, and combine with any earthy matters that may be present in the metal and coke. With these it forms a glassy compound, and by this means, the iron is freed from such impurities as it falls to the bottom. This *slag*, as it is termed, floats on the surface of the iron collected at the bottom, and frequently makes

its appearance at the tweres in a solid state, as will be afterwards more fully noticed.

Less coke is consumed when the fusion is pushed more rapidly to collect a greater quantity of metal for a heavy casting, as the iron besides is not required so hot as for smaller castings. About one half more coke, on the contrary, is consumed in melting metal for hollow ware and ornamental work, as these thin straggling castings require metal at a much higher degree of heat than the larger; and were such metal suffered to remain long in the bottom of the furnace, it runs a risk of getting too cold to afford sharp impressions of the moulds.

It sometimes happens that in the same course of melting with the same furnace, pieces are to be cast containing various proportions of different kinds of iron; in this case, to prevent an intermixture with the preceding or following charges, a considerable bed of coke is interposed. Though there be thus a waste of fuel, it is compensated by the improved adaptation of the castings to their specific objects.

The greatest source of waste, however, occurs when iron is taken from one furnace at the same time for light thin goods and for heavy work. For, as iron becomes less fluid the lower its temperature falls, it may be at first at such a temperature as will be suitable for the former kind of goods, while iron at a much lower temperature would suffice for heavier casts. We may observe that when iron is drawn too hot for the latter purpose, it must be allowed to cool before being poured, and the cooling is quickened by the introduction of scraps into the melted mass.

In large founderies there are usually three men engaged in conducting the business of a cupola; one acts as charger, another breaks the pigs into manageable pieces, and deposits them and the scraps of preceding meltings on the platform erected for the accommodation of the charger, who takes his station at the charging door; the third waits at the tapping hole, and supplies the workmen with the metal as they apply for it. The clay-plug is pierced with an iron rod, driven by a hammer, when metal is to be drawn; between the successive discharges, the hole is closed with a fresh lump of clay, applied by means of a pole seven or eight feet long, having a small disc of iron fixed at the end of it.

When the work of the cupola is over, the workmen commence to clear it out. To this end they break down the temporary clay work that narrows up the tapping door to one small hole. Having cleared this away, a plate-iron fence is set up opposite the door, behind which the workman stands, and over which he shoots a long rod kneed at the end, into the furnace, to loosen the contents consisting of the refuse coke and clay, and drags them out while yet hot; for if suffered to remain till cold, they would be congealed into one compact mass.

The pouring of the metal is managed in two ways. For strong pieces, whose moulds can be buried in the ground at seven or eight yards distance from the furnace, the metal may be run in gutters formed on the sand of the floor, sustained by iron plates or stones.

When from the smaller size or greater distance of the moulds, the melted metal cannot be run along the floor from the furnace, it is received in wrought-iron pots or ladles, lined with a coat of loam, which is laid in wet and dried in a stove. These are either carried by the hands of two or more men, or transported by the crane. In large founderies, there may be two or three cranes erected within reach of one another, thus affording a mode of conveying great quantities of metal to the most distant parts of the shop, by passing the ladle from crane to crane.

Fig. 11 represents the double hand ladle. At one end, the handle parts in two branches, *a b*, by means of which the workman inclines the ladle, and pours the metal into the mould. When the crane-ladle is used, it is suspended on pivots hung from the chain, and having been brought vertically over the gate hole of the mould, it is slowly inclined by the application of double-kneed iron bars to squarer parts of the handles.

After the metal is somewhat cooled, the mould is taken asunder, and the casting is *dressed;* that is, the excresences upon the edges of the casting are broken off with a hammer, and they are afterwards more carefully trimmed or chipped with a chisel when quite cold. Each casting always requires the melting of considerably more than its own weight of iron. This excess forms the gates and false seams, and supplies accidental strains in the mould. The gate pieces may of course be remelted with other scraps for future uses. The loss in founding, by waste of metal from every source, has been estimated at about six per cent. of the whole quantity of pig-iron used. By strict management, however, the rate of loss has been reduced so low as two per cent.

By melting the different varieties of cast-iron together in various proportions, the founder is always able to procure a material suited to his purposes, whatever be the property required. Indeed, the chief talent of the founder consists in discovering the most economical mixture of iron. One piece, for example, may be required to have great strength and tenacity to bear heavy weights or strains; another must yield readily to the chisel and file; a third must resist sudden alternations of temperature; and a fourth must be pretty hard. This main business of the founder is also in some measure accomplished by the diversity of character belonging to iron from different districts. Thus, the Staffordshire metal is generally remarkably fluid, and makes excellent small castings. The Welsh pig-iron is strong, and produces bar-iron of a very tough and good quality; whilst the Derbyshire, the Shropshire, the Scotch and other irons, all differ in like manner, each distinguished for the possession of some property not common to the rest.

The pig-iron produced in the operation of smelting is of very various qualities, according to the purposes for which it is wanted, and the circumstances under which it is manufactured. It may be divided generally into two kinds: foundery iron and forge iron, generally distinguished also as gray, and white iron—the former being employed in founderies, and remelted in the state of pig-iron for castings; the latter being applicable only to the manufacture of bar-iron. The reason of this peculiar adaptation of forge-iron is to be found in two circumstances: it is naturally too thick when melted to adapt itself to the shape of the moulds into which it is run; and, when cold, it is too weak and brittle to be of any service as cast-iron—a reason of itself sufficient to determine its unfitness for use in this capacity.

The two classes of iron above specified are usually recognised under five subdivisions, produced under different circumstances: No. 1, No. 2, and No. 3, foundery iron; No. 4, used indifferently for the foundery and the forge; and *white* iron, employed in the manufacture of bar-iron. The reason of the differences of these irons is to be found in their chemical constitutions. Carbon is the main element in combination with iron, pig-iron being in reality a carburet of iron, in the phraseology of chemistry; and the three distinct qualities of foundery iron, with which we are at present more particularly concerned, and which are distinguished mechanically by their relative hardness, are said to depend for their distinction chiefly upon the amounts of combined carbon which they hold; their hardness being inversely as the degrees of their carbonization.

No. 1, foundery iron, accordingly, possesses the largest amount of carbon, and so far apparently in the state of simple mechanical mixture. It is, indeed, charged with carbon to excess; when turned, free carbon may be observed flying off like powder. To effect this combination to its full extent, the quality of coke having the fibrous appearance of charcoal is selected, as being the purest carbon. The tendency of this combination is, as already remarked, to render the iron soft, and to make it very fluid when melted, so that it will run into the finest and most delicate moulds. This property peculiarly adapts No. 1 iron for the purpose of small, thin, and ornamental castings, and anything that requires a minute adaptation of the metal to the mould. It is distinguished in appearance by great smoothness on the surface of the pig, and in the fracture its aspect is of a large open grain, bright dark gray, intermixed with spots of a lighter colour and closer texture. It yields the most readily to the file and chisel. When broken, the pig does not ring, but falls asunder with a dull leaden sound.

No. 2, which is lighter in the shade than No. 1, is not so soft; it is not so fluid when melted, nor so smooth in the external appearance of the pig. It is closer grained, and more regular in the fracture; it is more tenacious—is easily turned and polished—and, being harder and stronger than No. 1, it is preferred for all the less delicate parts of machinery, where strength and durability are required.

The next quality of iron, No. 3, possesses less carbon than either of the other two kinds, and possesses still less fluidity when melted. It is still more minutely grained, and smoother

in the fracture than No. 2. It possesses a greater degree of toughness, as well as hardness, and turns out very strong and durable castings. It is therefore selected for castings liable to great and sudden strains, and exposed to constant tear and wear; tram plates, for example, heavy shafts, wheels, and steam-cylinders.

The next quality, No. 4, is used principally for forge purposes, though also extensively used for large foundery work. It is light in colour and closer in grain, which is sometimes scarcely distinguishable, than any of the preceding. It sometimes assumes a mottled appearance of gray spots on a light ground, arising from the occasional presence of some of the soft qualities of pig metal.

White iron is supposed to hold in union a very small portion of carbon, less than any of the preceding. It is totally unfit for founding uses, and is sometimes so thick as hardly to run into the pig-moulds, although they are purposely made very large. It is also very brittle ; so much so, that the largest and most unwieldy pigs may be readily broken by a blow from a sledge hammer. It is too hard to yield in any degree to the chisel; the fracture is of a silvery white colour, shining and smooth in the texture, with a foliated or crystallized structure. White iron is devoted exclusively to the forge.

There are individual exceptions to the preceding classifications in some of the iron made at Glengarnoch Iron Works, Ayrshire, and at Shotts Iron Works, where some of the softest iron yielded is very fine in the grain. The anomalous condition of this iron demands the attention of practical chemists. It is greatly sought after for making the fine polished small machinery of cotton mills.*

Though the different aspects which the gray and the white cast-iron assume in every respect, as in colour, strength, and fusibility, have been accounted for by supposing the gray metal to be more highly carbonized than the white, there are yet experiments of good authority which seem to contradict such an idea, and to indicate that, so far from this being the case, there is actually in many instances, an appreciably greater quantity of carbon in the white than in the gray iron. Respecting the external appearance and physical properties which the metal assumes, some chemists have been disposed to attribute the various aspects appropriated, rather to the mode of combination of the elements than to any absolute difference in amount of carbon, and they affirm that there is no necessary difference in this respect, inasmuch as the white variety may be changed into the gray by exposure to strong heat and cooling slowly, whilst the gray may be changed into the white by being heated and rapidly cooled. We know that the latter circumstance is taken advantage of in the practice of case-hardening wheels, anvils, and shot, for example, by being run in cast-iron moulds; likewise axle bushes of cast iron, which are run upon a metal core, as described in a preceding paper of this series.

But that there is a difference in the mode of combination of the constituents of gray and white cast-iron, amply sufficient to account for the diversity in mechanical properties which they present, the following remarkable results testify:—" According to Karstein, the carbon of the latter (the white iron) is combined with the whole mass of iron, and amounts as a maximum to 5·25 per cent., but in some specimens its proportion is considerably less. The former, on the contrary, contains from 3·15 to 4·65 per cent. of carbon, of which about three-fourths are in the state of graphite, and are left as such after the iron is dissolved by acids, whilst the remaining fourth is in combination with the whole mass of metal, constituting a carburet, which is very similar to steel. Gray cast-iron may hence be regarded as a kind of steel in which graphite is mechanically mixed."†

It appears, then, that though there be a greater quantity of carbon in the constitution of white cast-iron, all chemically united to the base, yet in gray cast-iron, notwithstanding that the total amount of carbon is less, the greater proportion of this substance is only mechanically united. So that the preceding observations on the various qualities of cast-iron, are, in reference to the more obvious elementary constituents, substantially correct.

There are other ingredients entering into the composition of cast-iron, in small quantities, though they have been considered by some to have a material influence upon the quality of the iron produced. This supposition, however, must be subjected to the test of experiment. The substances alluded to are manganese, silicon, and aluminum, which have been shown by Dr Thomson to be associated with the carbon in the composition of all cast-iron. He has found, also, that sulphur, calcium, and magnesium are sometimes present.‡

In concluding this part of our subject, we shall take the liberty of extracting the following hints for distinguishing cast-iron by the fracture from a well-known popular work,§ believing that they may be serviceable to the practical man.

When cast-iron is fractured, it exhibits a gray colour, sometimes approaching to dull white, and in other cases the colour is dark-gray, with spots nearly black. The lustre is sometimes metallic, resembling freshly cut particles of lead lying on the surface, and in other cases there seem to be crystals in the iron disposed in rays.

When the colour is a uniform dark-gray, the iron is tough, provided there be also high metallic lustre ; but if there be no metallic lustre, the iron, though soft, will be more easily crumbled than in the former case. The weakest sort of soft cast-iron is where the fracture is of a dark colour, mottled, and without lustre.

The iron may be accounted hard, tenacious, and stiff, when the colour of the fracture is lightish-gray, with a high metallic lustre.

When the colour is light-gray, without metallic lustre, the iron is hard and brittle.

When the colour is dull-white, the iron is still more hard and brittle than in the last case.

Fig. 5.

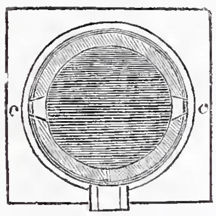


Fig. 6.

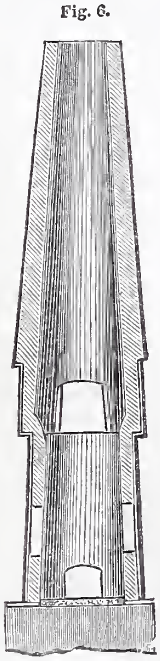
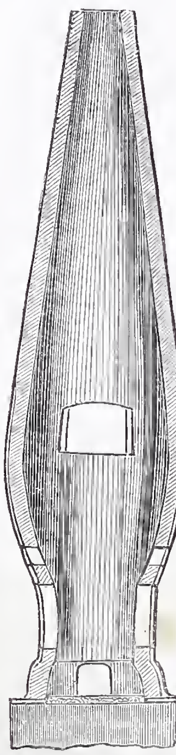


Fig. 7.



* The classification of pig-iron above stated is of great convenience, and is so far artificial, inasmuch as iron varies in quality, measured by fineness of grain, by minute gradations between the two extremes. Variation in quality is observable even in the same pig. Considerable latitude is therefore allowed in the classification of pig-iron.

† Turner's Chemistry, fifth edition.

‡ For further particulars on this point, see an article on hot and cold blast iron in the first volume of this Journal, page 123.

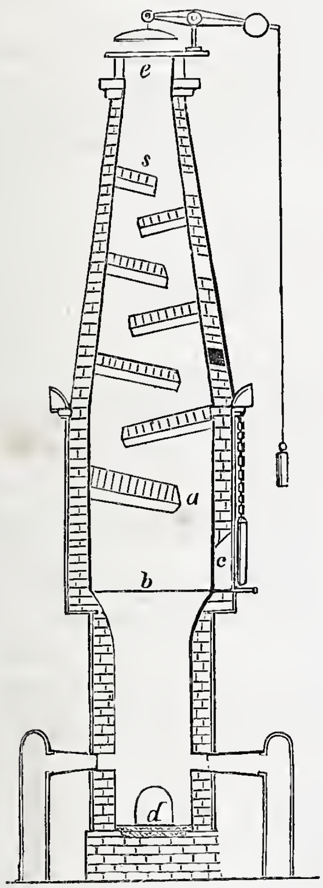
§ Grier's " Mechanic's Pocket Dictionary."

When the fracture is grayish-white, interspersed with small radiating crystals, the iron is of the extreme degree of hardness and brittleness.

When cast-iron is dissolved in muriate of lime, or muriate of magnesia, the specific gravity is reduced to 2·155 ; most of the iron is removed, and the remainder consists of plumbago, (graphite) with the impurities of cast-iron. A similar change takes place when weavers' paste is applied to iron cylinders. Sea-water, when applied for a considerable time, has the same effect. It takes three times as long to saturate acid with white cast-iron as with gray.

The best way to try the quality of a piece of cast-iron is, to strike its edge with a hammer. Should the blow make a slight impression, the iron must be in some degree malleable; and,

Fig. 8.



provided the texture be uniform, the specimen may be regarded as good for machinery. If, on the contrary, the hammer make no impression, and fragments fly off, the iron is brittle, and consequently bad. The soft gray cast-iron yields easily to the file after the outer crust has been removed, and is, in a cold state, slightly malleable.

We may state also, that the quality of iron in the melted state is readily judged of by a practised eye, from the nature of the agitated aspect of its surface. The mass of fluid seems to undergo rapid circulation within itself, inducing a constant tremor on the surface, having the appearance of ever-varying network. When this network is minutely subdivided, it indicates soft iron. If, on the contrary, the iron be thrown up in large convolutions, the quality of the metal must be hard.

We shall now turn our attention to an elucidation of the principles upon which cupola furnaces ought to be constructed and managed, founded upon experience of the working of various cupolas in actual operation. This leads us to a division of the subject into two points of inquiry, in the first of which the influence of form and size shall be discussed, with the view of determining the most efficient proportions of cupolas; and, in the second place, we shall endeavour to point out the most favourable conditions of fuel and of blast.

I. The influence of form and size :

In discussing this subject, the best and, indeed, the only true means of ascertaining the relative efficiency of variously made furnaces, is to compare the relative quantities of fuel consumed with the iron melted—economy of fuel, and rapidity of fusion, which generally accompany each other, being the touchstone of excellence. Little stress should be laid upon the simple average consumption of coke per ton of iron actually melted, as a criterion by which their relative capabilities may be judged of; for, as the initial charges of coke are so much greater than those which follow them, it is plain that the average consumption will be less, the greater the quantity of iron melted. Being thus subject to variation from the individual exigencies of the owners of the furnaces, the mere stated average consumpt of fuel is of no service in the present question, unless there be also specified the total quantities of iron melted at one time. We shall therefore state in detail the elementary data for each furnace examined, by which their relative capabilities may be accurately estimated.

The interior horizontal section of all cupolas is circular, however varied in other respects they may be; and the principal varieties of cupola may be arranged in four divisions, founded on the form of their vertical sections, taken through the trunk. First, those cupolas which taper anyway from the hearth upwards to the charging door, following generally a conical frustum; secondly, cylindrical cupolas, or such as are, for the most part, parallel in section under the charging door; thirdly, expanding cupolas, of which the sides expand from the neighbourhood of the tweres upwards to the charging door; and fourthly, cupolas of which the form is a combination of two or all of these figures.

Figs. 4, 6, 7, 8, 9, 10, are sectional views of particular cupolas, all of which are either actually at work, or have been so recently. They may serve as general examples of the principal forms of cupola-furnaces. They are all wrought with the coke prepared from Kilsyth coal. Figs. 4, 6, and 7, which are respectively taper, uniform, and expanding cupolas, are vertical sections of three furnaces at work in one of the most extensive iron-founderies in Glasgow.

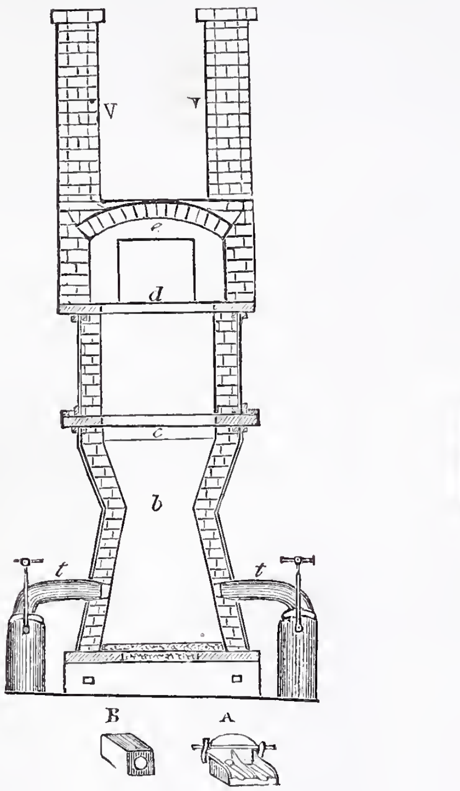
Fig. 8 is a sectional view of one of Yates' Patent Cupola Furnaces. It is, for the most part, parallel in the trunk *d b*, and expands towards the top, to meet the sides of the chimney at the level of the charging-door sill. The doorway *c* is formed in the side of an open rectangular portion of the building, which is of considerably larger dimensions than the trunk, and is the base of the chimney-stalk *b e*. Its longest dimension is represented in the drawing; and the chimney retains the oblong section till near the top, *e*, where it becomes square. It is furnished with seven arches (*a*, *s*, &c.), projecting from opposite sides alternately, and each overhanging the arch below it. The arches are seen in section, in the line of the crown of each arch. The door, which is of brick built in an iron frame, is hung over two pulleys by a chain, and balanced by a counterweight. The chimney is also furnished with a damper at *e*, in the manner of forge chimneys.

Fig. 9 is a vertical section of a cupola lately erected at the Falkirk Ironworks, as a substitute for three smaller cupolas which were previously used there. Its form of section is a combination of the tapering and parallel outline. It is overarched too, just above the charging door; there being four small chimneys, one at each corner, of which two are shown, for leading off the volatile products. The furnace is blown by a Vaughan's Patent Blast, of six chests, having a pressure of 12 ounces to the square inch; which is, moreover, heated to the temperature of 442° F., the melting point of tin. *a*, the hearth, from which the furnace is contracted to the waist *b*, which is the smallest part of the furnace. It next expands into the cylindrical portion *c d*; *d*, the charging door; *e*, the arch; *d e*, a square chamber, communicating with the four vents, of which two (*v v*) are seen, and the interior of them dotted in; *t t*, the tweres. A is the fauld-plate, having two tapping holes in it;—it is fixed against the furnace by a rod. B is a bush of brick, in two halves, for the twere nozzles.*

* A more minute description of the blowing machine and heating apparatus is reserved for the second part of this paper.

Fig. 10 represents in section a smaller cylindrical cupola, which was, some time ago, regularly at work, but has since been interdicted as an infringement on Yates' patent, on account of the sem circular dome erected over it. *a b* is the trunk; *b*, the charging door; *c*, the dome, having a small chimney, *d*, at the summit, which was closed on the top by a plate bolted on by flanges; outlets, three in number, (of w ich two are shown n section, and all three are seen in plan, fig. A,) were provided in the chimney, pointing obliquely downwards, for the escape of the gases. For the re son already mentioned, the dome is replaced by a common chimney, represented by a dotted line; *e* is the summit; and the cupola is now wrought in the ordinary way. The dome was an original idea of Mr. Joseph Buchanan's, who superintends the furnace, and who applied it two years and a half ago.

Fig. 9.



After the preceding brief outlines of these furnaces, we may add their principal dimensions in the same order.

Fig. 4.

The taper cupola :—

	ft.	in.
Diameter at the hearth and at the tweres (*c*),† . .	4	10
Diameter at the sill of the charging door (*f*), . .	3	0
Diameter at the top of the chimney (*g*), . . .	1	6
Height from the base-plate to the sill of the charging door (*d f*), ...	8	4
Height from the door-sill to the top of the chimney (*f g*),	18	0

Fig. 6.

The cylindrical cupola :—

Diameter at the hearth,†	3	3
Diameter at the charging-door sill, ...	3	0
Diameter at the top of the chimney, ...	2	6
Height from the base-plate to the sill of the charging door,	7	0
Height from the door-sill to the top of the chimney, .	16	0

† These furnaces have not strictly the form assigned to them; but the variations are, comparatively, unimportant. The parallelism of part of the first one will indeed be so far favourable to it, in comparison with the others. The second furnace, it will be observed, has three inches of taper in seven feet.

Fig. 7.

The expanding cupola :—

	ft.	in.
Diameter of the receptacle at the hearth,* . . .	4	0
Diameter at the tweres, ...	3	0
Diameter at the sill of the charge-door, ...	6	0
Diameter at the top of the chimney, ...	1	10
Height of the receptacle, ...	1	0
Height of the parallel part at the tweres above the base,	4	6
Height of the sill of the door above the base, . .	10	0
Height of the top of the chimney above the door-sill, .	18	0

Fig. 8.

The patent cupola :—

Diameter of the trunk (*d b*), ...	3	0
Length of the rectangular space opposite the charge-door (*b*), ...	5	0
Breadth of ditto, ...	3	9
Length and breadth at the top of the chimney (*e*), .	2	0
Height from the hearth of the parallel part of the trunk,	7	0
Whole height of the trunk, to the sill of the charge-door (*d b*), ...	10	0
Height of the chimney above the door-sill (*b e*), . .		
Height of the first arch, *a*, above the door-sill (*b a*), .	3	6
Width of the opening at the first arch (*a*), . .	1	4

Fig. 9.

The arched cupola :—

Diameter at the hearth (*a*), ...	4	6
Diameter at the waist (*b*), ...	3	0
Diameter in the cylindrical chamber (*c d*), . . .	4	8
Width of the square chamber (*d e*), ...	5	8
Width of the vents (*v*), ...	0	9
Height of the waist (*a b*), ...	6	0
Height of the lintel square plate (*a c*), . . .	9	6
Height of the sill of the charging door (*a d*), . .	14	0
Height of the square chamber to the crown of the arch (*d e*),	3	8
Length of the vents, ...	8	0

Fig. 10.

The dome cupola :—

Diameter of the cylindrical trunk (*a b*), . . .	2	0
Diameter of the cylindrical chamber and dome (*b c*), .	3	0
Diameter of the chimney (*d*), ...	0	6
Height from the hearth to the charge-door (*a b*), .	7	0
Height to the summit of the dome (*a c*), . . .	8	4
Height of the chimney above the door-sill (*b d*), . .	5	6

Fig. 10.

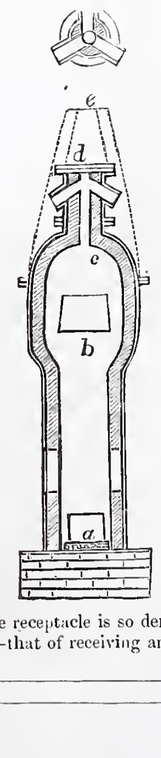
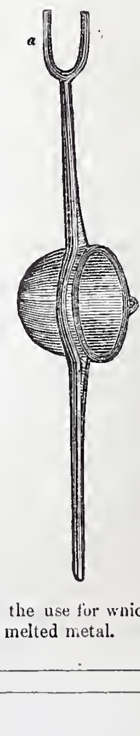


Fig. 11.



* The receptacle is so denominated, from the use for which it is intended—that of receiving and collecting the melted metal.

The following is a tabular statement of the several results which the experience of these cupolas affords:—

	1	2	3	4	5	6	7	8	9	
Name of Cupola.	Initial charge of coke.	First charge of iron.	Second charge of coke.	Second charge of iron.	Running consumpt of coke per ton.	Coke required to melt 5 tons.	Rate of melting per hour.	Pressure of blast, in ounces.	Diameter of tweres, in inches.	Remarks.
Taper,	12	12	$1\frac{3}{4}$	20	$1\frac{3}{4}$	20	5	4	$5\frac{1}{2}$	
Cylindrical,	$8\frac{1}{2}$	6	$1\frac{1}{2}$	15	2	18	3	4	$5\frac{1}{2}$	Blast cold. Metal melted very hot for hollow ware, &c.
Expanding,	$8\frac{1}{2}$	10	$1\frac{1}{2}$	20	$1\frac{1}{2}$	$15\frac{1}{4}$	6	4	$5\frac{1}{2}$	
Patent,	8	10	1	10	2	17	3	6	7	Blast cold. Metal temperately hot for ordinary jobbing.
Overarched,	10	10	$\frac{3}{4}$	10	$1\frac{1}{2}$	$16\frac{3}{4}$	5	12	$5\frac{3}{4}$	Blast heated to 442° F. Metal very hot.
Domed,	3	12	$\frac{3}{4}$	8	$1\frac{7}{8}$	$12\frac{3}{8}$	2	$3\frac{1}{2}$	6	Blast cold. Metal temperately hot.
Common,	3	9	$\frac{3}{4}$	5	3	17	$1\frac{1}{4}$	$3\frac{1}{2}$	6	

The first four vertical columns exhibit the first four successive charges, in cwts., with which the furnaces individually are supplied. It is unnecessary to extend this account farther, as the succeeding charges are made in the same proportion as the two last, stated in the third and fourth columns.

The fifth column states this proportion under the running consumption of coke, in cwts., per ton of iron, being taken independently of the initial charges in the first and second columns.

The sixth column states the consumption of coke by each furnace in melting the first 5 tons of metal.

The seventh column expresses the actual average rate of melting of each cupola.

The eighth and ninth express the pressure of blast applied to each furnace, and the diameters of the twere nozzles.

(1.) The principal unavoidable loss of heat takes place by radiation from the outside of the cupola, and by conduction through the hearth. In cupolas similarly formed, and which raise the melted metal to the same temperature, the amounts of loss by radiation must be in the ratio of their diameters; say at the tweres.

(2.) And as the diameters at the tweres are as the square roots of the areas at the same level, the loss by radiation will also be as the square roots of the areas; showing that the amount of loss, relative to the capacity of the cupola, decreases rapidly as the cupola becomes larger.

(3.) In the same circumstances, the loss by conduction through the hearth will be in the ratio of the areas of the hearths; and, therefore, also in the simple ratio of the capacities of the cupolas.

(4.) The loss of heat by the escape of volatile products through the chimney will be in the ratio of the horizontal surface of charge, and, therefore, also in the simple ratio of the capacities of the cupolas.

(5.) In the same circumstances, and, supposing the charges of metal to be in the ratio of the horizontal areas. the charges of fuel will be in a greater ratio the smaller the cupola, by as much as will account for the greater relative loss by radiation.

(6.) It is evident, too, that, on the preceding suppositions, the quantity of air thrown into the furnace ought also to be in a greater ratio the smaller the cupola; in fact, that the quantity of air ought to be in the ratio of the quantity of fuel.

(7.) In the same circumstances, the *rapidity* of melting will be the same in all; while the *absolute quantities* melted will be in the ratio of their horizontal areas at the tweres.

(8.) Under these conditions, therefore, the horizontal area or capacity at the tweres will be the measure of the melting power of cupolas similarly formed; that is, of the absolute quantity of iron brought down.

(9.) It is easily perceived, too, what is really a matter of fact, that, of cupolas similarly formed, whether taper or cylindrical, the larger are invariably the more economical, provided they be wrought proportionally to their several capacities.

(10.) The importance of this condition is evident, on comparing the initial charges with those that succeed them. For an example, we may refer to the preceding table; in which we find that, while the initial charges of coke for the taper and cylindrical cupolas respectively are 12 and $8\frac{1}{2}$ cwt., the running consumption of fuel for the former is stated at $1\frac{3}{4}$ cwt. per ton of metal, while that of the cylindrical furnace is as much as 2 cwt. per ton; and, notwithstanding this latter disadvantage, we find that the quantities of coke required by each to melt 5 tons are 20 and 18 cwt. respectively. Thus, while the running consumpt by the second furnace is the greater, the total expense of fuel for melting 5 tons is less, on account of the considerably less quantity of the initial charge. But, by continued melting, the taper would at last gain upon the cylindrical in economization of fuel; and this would take place when they had melted 13 tons each, the consumption of fuel in both being 34 cwt. This comparison is intended merely to show the economical importance of initial charges, without reference to the relative merits of the taper and cylindrical cupolas.

(11.) The rule stated in article 8 would hold in comparing cylindrical and taper cupolas, were their essential circumstances equal, which they are not. The successive charges of fuel and iron, as they are delivered, experience the action of the redundant heat evolved at and above the tweres. In the course of their descent, they become more intensely heated, till the fuel is brought into a state of active ignition; and the iron melts and falls to the hearth, rising in temperature as it descends through the mass of burning coke. It is of importance, therefore, to economize the heat which comes off with the volatile matters constantly rising from the tweres. This is obviously much better secured by the cylindrical than by the taper furnace, as the former exposes a greater mass of superincumbent material for the absorption of the heat. It is found, accordingly, that, of taper and cylindrical cupolas of the same diameter at the tweres, the former requires more fuel and blast than the latter, to bring down the same quantity of iron at the same temperature. The idea that the taper cupola keeps down the heat better than the other is of no force, seeing that there must be less charge in stock, so to speak, to derive the benefit of it.

(12.) The initial charge of fuel must always fill up the cupola above the tweres at least, that it may receive directly the action of the blast. But the taper cupola has a greater capacity below the tweres than the parallel one, and therefore requires more. While the main design of the initial charge is to heat the furnace, there may on this account be more than sufficient for the purpose. There is not so much liability to waste in the cylindrical furnace; but at the same time, by the greater expanse of hearth in the other, the metal brought down is more securely kept hot by exposure to a large surface of fuel; and, besides, advantage may be taken of the superfluous fuel, by moderating the following charges.

(13.) Again, in charging parallel cupolas, the fireman can more precisely distribute and regulate the proportions of his charges for the purposes he may have in view than in dealing with taper cupolas. For, in the former, the materials descend regularly, without altering their arrangement, till they reach the neighbourhood of the tweres where the iron ought to be melted, and the unconsumed coke is pressed gradually and equally down to make way for the superincumbent charge. Thus the process goes on in a secure and well-ascertained manner; whereas, in the taper cupola, the men are inconvenienced for want of space to deposit their charges, and the materials having to spread into the larger expanse below the door, they cannot do so equally; and, by the unequal mixture of material, the iron is unequally

heated. We believe this objection especially applicable to furnaces formed in the manner of the lower parts *a b c* of the Falkirk cupola. To this individual furnace, indeed, the objection is not so applicable by reason of the great depth of the space *c d*, through which, while the materials are descending, they become well heated up by the time they arrive at the waist *b*. But, in furnaces of the complete form *a b c*, while the charge may be heaped above the line *c*, it gets packed in the space *c b*, which is just a hopper that leads the charge to the mouth of the taper part, and often "hings" at the waist for some time. In the interval, of course, the body of charge in *b a* is falling away clear of what is overhanging at *b*, till at last this is undermined by the constant action of the heat upon it, and tumbles down in confusion; the pieces of metal lodged in one part and the fuel in another, producing the phenomena of a quantity of solid roasted pigs passing the tweres unmelted, which must afterwards so far cool down the liquid metal collected at the bottom. While we condemn the contraction in the Falkirk furnace, such as it is, we believe that in the cupolas employed at Carron Iron Works, the contraction at the waist is still more excessive, being, as we are informed, not more than 18 inches in diameter. The mischievous tendency of this contraction is quite apparent; and we see no other possible reason than one we have already noticed, and another which was once given that the pigs should he induced to descend head foremost, to receive the more complete application of the hot hath. There is no force in this idea; for, it matters not how the pieces of metal lie, if they he enveloped in heat above and below. We are convinced that the Falkirk cupola would be greatly improved in its action at least by being altered into a uniformly cylindrical cupola.

(14.) The importance of returning as much as possible of the fugitive heat to the charge was taken into account in the designing of the expanding cupola, fig. 7. This cupola, three feet wide at the tweres, is of douhle this width at the charging door, where it is six feet wide. The expansion of the form of the furnace springs at a level little above the ordinary level of the tweres, so that it may he the more gradually accomplished, which prevents the occurrence of "hinging" or blocking up. And, indeed, the form of the cupola was so calculated that the metal should be melted before reaching the parallel part at the tweres, which is in reality the fact. The great expanse of this furnace at the charging door admits of the application of heavy charges with great advantage, and its general spaciousness well adapts it for the conservation of the heat. Its superiority to the cylindrical and taper cupolas is evident from the inspection of the tahle. In the first place, the accounts of the initial charges of coke show that, notwithstanding the great difference in their capacities, the second and third in the list are supplied with equal quantities. This is easily accounted for hy the nearly equal diameters at the tweres. The taper cupola requires a quantity one-half greater to cover up its capacious hearth. The third furnace again bears two-thirds more iron in the first charge than the second, and not much less than the first. And, lastly, the running consumption of fuel per ton of metal is one-third more in the second than in the third furnace, and one-sixth greater in the first.

The last point of comparison to which we shall direct attention is the relative melting powers of these furnaces. Here again is manifested the superiority of the third furnace; for, while it melts with ease six tons in the hour, the cylindrical furnace melts only half the quantity, and the taper cupola, though nearly five feet wide, brings down at the rate of just five tons per hour.

(15.) This proves, in the first place, that of the last two furnaces, the cylindrical and the expanding, which are hoth three feet diameter at the tweres, the latter is undoubtedly superior to the former; and, in the second place, that the third furnace, as it is, is superior to the first; but the idea of its superiority is much enhanced when taken in connexion with the disadvantage at which it stands, in being so much smaller in diameter at the tweres than the taper cupola. Fancy a five feet furnace expanding to ten feet diameter at the charge door, and we should soon see the difference.

The idea of a literally inverted cone as a form of cupola has also heen tried. The tapping hole was situated at the apex of the figure; and, as might have heen anticipated, it soon became choked up with refuse. The general idea, however, was excellent. In the expanding cupola, on account of the comparative narrowness at the tweres, provision is made in the re-expansion at the hearth, named the receptacle, for holding a quantity of metal, and preventing interruption from the accumulation of slag.

(16.) But the economical results in the use of the expanding cupola are to be ascribed partially to its unusual depth of space above the tweres; its whole depth from the hearth to the charge door heing ten feet. A few years ago a cupola was erected at Dalkeith Foundery of the same height, in place of a small one, and it was found of course to reduce considerahly the expense of fuel. These dimensions have, however, heen far exceeded by the extraordinary depth of the Falkirk furnace, which is no less than fourteen feet high. This is one of the best redeeming features of that furnace, and it might have been advantageously repeated in the expanding cupola.

(17.) The same idea of the conservation of the fugitive heat is also brought out in the super-huilt arch of the Falkirk furnace, the impinging arches and the damper of the patent furnace, fig. 8, and in the dome-covered furnace, fig. 10. In regard to the first of these applications, it is not considered by those under whose management the furnace is wrought to he of much service. It is likely that the advantageous depth of the furnace nearly does away with the necessity for the arch. In the dome furnace, on the contrary, the beneficial effect of the dome and small chimney was very remarkable, as is evident from the accounts of the work of the furnace with the dome and with the simple taper chimney, as given in the preceding tahle. There is no doubt that a greater depth of trunk over the tweres would have produced the same result. Although we have described the short chimney attached to the dome as being close at the top, and having three lateral vents for the gases, yet the furnace was generally wrought with an open top, as, otherwise, it rather too severely retarded the escape of the gaseous products.

(18.) The Patent Cupola Furnace was invented hy Mr James Yates of Rotherham in 1840; and in his prospectus of its advantages, he claims for it a great superiority over other existing cupola furnaces, in respect of the economy of fuel, quality of the metal melted, rapidity of melting, and removal of the annoyance of smoke, heat, and spark-dust.

We may remark, in the first place, as to the trunk of the patent cupola, that it is of an ordinary cylindrical form, being nothing different from other cupolas of the same kind, except inasmuch as it is widened at the top to meet the sides of the oblong chamher which forms the bottom of the stalk. According to the transverse vertical section of the furnace, not given in the drawing, the chamber is but $4\frac{1}{2}$ inches wider on each side than the trunk, being 3 feet 9 inches wide, while the latter is 3 feet in diameter. The chimney retains the ohlong horizontal section throughout its height till near the top, to he sufficiently capacious to receive the reflecting arches. Its complicated chimney is the principal novelty in the patent furnace; the main object of its peculiarly arched apparatus is to reflect the radiant heat thrown off the contents of the furnace, and to detain the heat contained in the current which winds its way among them. It appears to us that the first and certainly the principal object is effected by the first two arches alone, and we are at a loss to know the importance of the upper five arches. Allowing that they do at first deprive the current of a portion of its heat, to what good purpose is this effected? The heat does not go hack to the furnace; they cannot transmit their acquired heat downwards through a medium hotter than themselves; for, of course, the lower arches are hetter heated than the upper ones. Though the current is made to follow a course nearly as tortuous as the flues of any patent steam boiler, it must he understood that there does not exist the same good reason for the flexures of the channel, inasmuch as it is not the genius of Yates' Patent Cupola Furnace to melt metal up the seven-arch chimney.

The principal effect of the arches seems to he that they lay the dust that ascends with the current, and certainly it is an object to be delivered from such an annoyance. But even this end would be better effected, if the inclination of the upper arches were inverted. Solid particles of matter, suspended in any agitated fluid medium, seek refuge, and remain in the quietest spots in such an element. If, then, the upper arches were constructed with an inclination upwards, their superior surfaces, on which the dust settles, would be more completely isolated from the agitation of the current, and would, therefore, in their recesses, afford a hetter refuge for the sparks in their upward progress.

Besides, it is well known how subject the patent cupola has been to the occurrence of explosions of collections of inflammable gas under the arches, and that it requires the constant attention of the fireman to manage it properly. And the furnace having once been charged, there is no opportunity of renewing the supply till the charge be blown down; the reason of which is, as we are informed, that when the furnace is fairly set agoing, the charging door must be let down over the opening; and, by maintaining the strength of the current, to prevent the detention of inflammable gas under the arches, the sources of explosion are removed.

After all, therefore, we decidedly object to such a pile of arches *in toto*. We have heard of an elegant philosophical experiment, in which small cups are suspended at different elevations in a vessel of water, kept boiling to maintain the water in a continued state of agitation; the vessel is further supplied with a quantity of comminuted solid material, which partakes of the motions of the fluid. It is observed, that the small vessels or cups, act as "harbours of refuge" for the particles flying about in the water; for, in the course of their circulation, the latter are successively deposited in the cups, until the water is left clear.

Now, we think a more elegant application of this principle of the pursuit of quietude might have been made to the chimney of the patent cupola, inasmuch as a few huge pots, suspended in it at discretion at different elevations, would not only evanish the obnoxious particles, but would at the same time afford the advantage of a direct passage for the medium from which these particles would be delivered. We do not insist upon *iron* pots, as we suspect these, themselves, would quickly vanish; let us have substantial vessels built of the infusible brick of the patent arches, to a circle of eighteen inches diameter by eighteen deep.

Further, the substitution of the interdicted dome of the small cupola, fig. 10, for the lowest arches of the patent furnace, of which the peculiar function is to reflect the radiant heat from below, would, in our opinion, do fully as well, and would also allow the erection of a round chimney embracing the dome. In the centre of this dome, a sufficient opening would be allowed as vent-way, over which, to afford still farther reflecting surface —one of our peculiar pots might be hung, at a distance proper for affording the necessary passage to the current.

Our readers may indict us for trifling with the subject of the patent cupola in the few foregoing remarks; but we assure them that we express our impartial opinion; and, that we may not be chargeable with the reproach of special pleading, we shall set forth as impartially what we opine to be the merits of the furnace.

In the first place, then, we observe that the patent cupola possesses a good common-sense cylindrical trunk of about ten feet high to three feet diameter. The inventor has avoided the errors in some other modern cupolas; but its efficiency would have been much enhanced by being constructed with an expanding throat, and with still greater relative depth. In the second place, the idea of the arches is good so far as they serve the purpose of reflecting the heat. But this virtue being confined to the first and second from the bottom, the rest are superfluous, except as shelves for accumulating the spark-dust; and indeed, as we have already found, they are positively injurious. It must be acknowledged that the characteristic of a reverberatory furnace was first bestowed upon the founder's cupola by the patentee, and that the idea has been plagiarized, in not a few instances, to the advantage of those who adopted it. While we condemn such conduct, we still insist that width and depth of space below the charging door ought to be the chief idea to be realized in the construction of an "improved furnace," and then no doubt the reverberatory surface will be commendable as an auxiliary idea. In the third place, the application of what is erroneously termed a damper to the top of the chimney constitutes a peculiar feature in the furnishing of the patent cupola. The "damper" is applied with the view of modulating the "draught" of the furnace; and, before making any further remarks, we would say, as in duty bound, that the damper is good in so far as it reflects the fugitive heat upon the charge. Accordingly, in one instance of a common cupola with an open chimney, to which an interdicted damper was lately applied at the top of the chimney, when the damper was nearly closed, the current which was throttled yet immediately reacted, and burst fiercely out at the charging door; at the same time the effect upon the charge was surprising, as the iron was brought down with amazing rapidity. This phenomenon clearly proved the beneficial effect of an overarching upon the furnace—for such virtually did the chimney become—as the smoke, &c., had to find vent by the charge door. But the damper is clearly inapplicable to the Patent Furnace, as it cannot be supposed to send down the heat among the arches like a zigzag streak of lightning, unless indeed it were gifted like the famous fowlingpiece which could send a bullet round a corner. But there is a vague notion current among some, that a damper somehow or other "keeps down the heat." For our own part, we cannot understand this mode of action: the heat can be kept down only by keeping down the current, which is inadmissible; and the plain fact is, that the damper acts simply as a reflector, which purpose is already served in the patent cupola by the lower arches, and this leads us back to our dome apparatus already suggested. Finally, we would observe, that though the idea of the application of dampers to founders' cupolas was very likely inferred from that of dampers already applied to forge and other draught furnaces, the action of the so-called damper is evidently not at all analogous to dampers applied to furnaces which are kept in action by the force of the *draught*. In the latter case, the function of the damper is to strengthen or weaken the draught, which is analogous to the regulation of the blast of founders' furnaces.

But "the proper value of a thing—being just as much as it will bring," what is the actual performance of the patent cupola? Now in reference to this point, we have been told by founders who use the patent furnace, in answer to inquiries respecting it that this is a "secret in the trade." Another has committed himself so far as to state in his simplicity that a smaller cupola did better than a larger one. And what is better, another has told us that he has been cheated into the adoption of the patent cupola, and that it is with considerable difficulty he can get up a steady flame over the charge. Passing these circumstances, however, we find on referring to what we are sure is a true account in the table, that the running consumption of fuel by the three feet patent cupola, is just the same as the running consumption by the common three feet cylindrical cupola, though the former receives a larger quantity of iron at the first charge. But still further, on referring to the column of remarks, it is found that while this individual patent furnace melts metal only sufficiently hot for jobbing castings, the other cupola with the same consumption of fuel turns out metal hot enough for the thinnest hollow ware. Now it is certain that nearly one-third of the coke consumed in melting iron for hollow ware castings, would not be required in melting metal for ordinary castings. If we compare also the rates of melting, they are but equal. These facts we consider decisive of the merits of "Yates' Patent Cupola Furnace."

(19.) While we are upon this subject, we shall just notice the performance of the Falkirk overarched cupola. It stands a fair comparison with the expanding cupola, though certainly we expected to be able to furnish a more favourable account of it, considering the original application of the hot blast to it, and the usual pressure of $\frac{3}{4}$ lbs. per inch of the blast supplied to it, and notwithstanding the defects in its form, already pointed out.

(20.) We have yet to turn our attention to the formation of chimneys. Mere height of chimney is not found to exercise any material influence upon the condition of the furnace. Open chimneys built directly over the charge ought to be very capacious immediately above the charging door to allow the free escape of the smoke, &c., which rises from the charge, as it has been found that, when suddenly contracted at that part, it is apt to throw back the smoke. For the mouth of the stalk when unprovided with a damper, there is a certain least size which is just sufficient to allow the smoke to pass freely away, while the effective reverberatory surface will be the largest possible. For example, the three feet expanding furnace has a chimney of 22 inches diameter at the mouth, which allows a free vent; whereas, when it was formerly 16 inches at the mouth, and also straighter above the charging door, the firemen were greatly troubled with the gusts of smoke and flame from the door. The size of the mouth is no such nice matter when the cupola is furnished with a damper; for, by this the size of the opening may be nicely adapted to the strength of the current, and at the same time it throws down a portion of the radiant heat. If open cupola chimneys were made shorter than they are usually, so as to approach

the dome cupola in form, they would no doubt be more effective in "keeping down the heat."

In our next, and last of this series of papers, we shall endeavour to point out the most favourable conditions of fuel and blast.

WHITHAM'S EXPANSIVE STEAM ENGINE.

This is an attempt to effect the same purpose by means of one cylinder that is accomplished by two on Woolf's plan, and thereby to avoid the complexity of parts, and of course to reduce the expense of the engine consequent upon the use of two cylinders.

The engine is worked by three descriptions of pressure, resulting from the same steam, and operating within the same cylinder; and performs in succession all the several functions of the three varieties of steam engines, distinguished as high pressure, expansive pressure, and direct atmospheric pressure. These results are obtained in the following manner:—The piston, as shown in the sectional drawings below, partakes of the qualities of piston and plunger. The lower part, or piston, fits the cylinder, and is made to work steam-tight in the usual manner. The upper, or plunger part, rises from the piston in the form of a hollow cylinder; it is longer than the steam cylinder, and passes through the cylinder cover and stuffing box. The piston rod rises through the middle of the plunger, and is connected to the cross gudgeon of the parallel motion; it might, however, if preferred, be attached to the top of the ram or plunger.

The valvular process is a modification of the single slide, enclosed in a valve box in connexion with the boiler. Three steam passages, *f g h*, open through the back part of this box; the uppermost of which leads to the upper part of the cylinder,

Fig. 1.

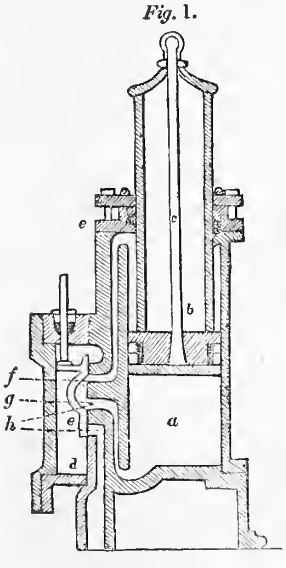
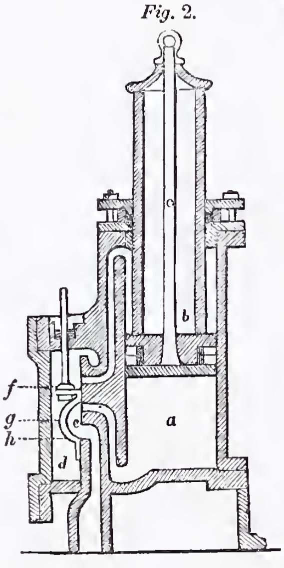


Fig. 2.



the middle one to the lower part of the cylinder, and the lowest to the condenser. The lower part of the valve is extended lengthways in a flat surface, so as to cover the eduction passage when the piston is making its ascending stroke, as shown in fig. 1; during which time, the upper and lower passages leading to the cylinder are connected by the cavity within the valve, as will be seen at *g* in fig. 1. All the other parts of the engine are similar to the corresponding parts of other reciprocating condensing engines.

When the piston is descending, the slide valve is in the position shown in fig. 2, and is admitting steam from the boiler into the annular space between the plunger and cylinder, which acts upon the annular surface of the piston; the middle and lowest passages from the valve box are at the same time connected as shown in fig. 2, and form a communication between the under surface of the piston and the condenser. A vacuum consequently exists beneath the whole piston, while the direct pressure of the atmosphere upon the whole area of the plunger, together with the high pressure steam upon the annular surface of the piston, and an additional pressure on the annulus, equal to that of the atmosphere, over and above the direct high pressure from the boiler, resulting from the vacuum beneath, combine their united forces to produce the descending stroke. To illustrate this more clearly, suppose the area of the piston to be 100 inches, area of annulus 25 inches, area of plunger 75 inches, and the steam in the boiler 45 lb. per inch above atmospheric pressure, the case would stand thus:—

Pressure of steam on annulus, . . .	$45 \times 25 = 1125$
Vacuum under annulus, ...	$12 \times 25 = 300$
Direct atmospheric pressure on the ram or plunger, ...	$12 \times 75 = 900$
Total effect of the descending stroke in lbs.,	2325

When the piston has arrived at the bottom of the cylinder, the valve is in the position shown at fig. 1; the lowest or eduction passage is shut; the middle and upper passage leading to the lower and upper ends of the cylinder are connected; and all communication is cut off between the boiler and cylinder, also between the cylinder and condenser. In this state: that is, when *no steam is being received from the boiler*, that which during the preceding descending stroke occupied the annulus, is now acting against the plunger with its whole force of expansion for the ascending stroke, while the annular surface of the piston is rendered passive, in consequence of the pressure above and below being equal. From this it will be understood, that the only steam required, to produce a descending and an ascending stroke, is just so much as will fill *once* the annular space between the cylinder and plunger, and which may be of any pressure consistent with safety.

The difference between the area of the cylinder *a*, and the area of a section of the plunger *b*, determines to what number of times a given volume of steam shall expand to produce the ascending stroke; for instance, if the area of the plunger be 3, and that of the cylinder 4, the steam will expand from one volume to four; and by increasing the circumference of the plunger and diminishing the annular space, the principle of expansion may be carried to the utmost extent.

The saving of fuel consequent upon this mode of working high-pressure steam, namely, by directing its expansive energies upon *large areas*, will be evident when it is considered,—1st, That a given volume of steam produces, in the first instance, as much power during the descending stroke, as steam of the same description produces in any ordinary high-pressure engine. 2d, That the *same steam*, still retaining unimpaired its elastic pressure, but which in other engines is suffered to escape, is next directed so as to act against the plunger, (which is three times the area of the annulus,) for the ascending stroke, and that too *in the same cylinder, the temperature of which far exceeds the medium temperature of the steam during its expansion.* 3d, That the same steam reduced by previous expansion to the state of low pressure, is condensed as usual, leaving a vacuum of *four times the original capacity* of the steam employed.

These conditions have been rigidly demonstrated as respects the expansive action of steam generally; and as Mr Whitham's engine is based upon the established principle, and is more simple in its construction than those hitherto adopted, it may be fairly expected to achieve at least an equally economic administration of the steam employed in working it.

AGRICULTURE.

CHAPTER IV.

THE KINDS AND VARIETIES OF BRITISH DOMESTICATED ANIMALS.

The domesticated animals used for food in this country, are the sheep, the ox, the pig, and the different varieties of poultry. What follows is an account of the most general properties of the more important varieties of them:—

1. Sheep.—The origin of the sheep, in its wild state, is quite lost, and from the very earliest period of history, it has

been a domesticated animal. Of British sheep, we may enumerate—

a The Shetland Sheep.—This is a very small animal, half-wild in its habits, and yielding a fleece of very fine and soft wool, which, however, contains a considerable admixture of hair. The wool is much used for making flannels and hose, for wearing next the skin.

b The Welsh Sheep.—Welsh sheep are small, very hardy, semi-wild animals. Their wool is considered particularly suitable for making flannels, and their mutton constitutes one of the finest varieties that we possess.

c The Blackfaced Scotch.—This is a small breed, not exceeding, perhaps, fifteen or sixteen pounds to the quarter. But of all sheep, its mutton is the most delicate. There is, however, an opinion, perhaps not well founded, that blackfaced mutton is not good until the animal to which it appertained is three, five, or even six years old. The fleece weighs about three pounds, and is not in request.

d The Cheviot Sheep.—This is a northern mountain breed, in much estimation, and the members of which are considered to excel the last mentioned, in being earlier ready for the butcher, in their larger size, in the superior fineness of the wool, and in being, in virtue of having their instincts more highly developed, more easily managed in wild pastoral districts.

e The Southdown Sheep.—This breed, one of the best that we have, was originally produced upon the Suffolk-downs; but it has succeeded, and been liked, wherever it has been introduced. These Southdown sheep are distinguished by their docility, their excellent mutton, which weighs nearly twenty pounds a quarter, and their wool, which is in great estimation.

f The Leicester Sheep.—This is an entirely artificial breed, produced in comparatively modern times. Of all sheep, the members composing it become fit for the butcher in the shortest time. At fifteen months old, a Leicester sheep will weigh from 25 to 30 lbs. the quarter; and its fleece at that age will amount to six or seven lbs. It is, however, tender in its constitution, and of late its mutton has not fetched so good a price as that of the other kinds mentioned above.

2. Ox.—The cattle at Hamilton Park, and at Lord Tankerville's, are believed to be the descendants of the, or at any rate an, ancient wild indigenous race of cattle. Of the many varieties now known in the British islands, we may mention—

a The Shetland Ox.—This breed is of Scandinavian origin, and was probably introduced into the Shetland islands when they were under the rule of the Norwegians. Shetland oxen are very small, and remarkably ill-proportioned, yet their flesh is, perhaps, the finest of any, and many of the cows are good milkers. They are extremely hardy. We have noticed some in our own possession, however, to be extremely nice about their food, and to reject, or eat but sparingly, both turnips and cabbages, which were apparently much relished by the other cows in the same byre.

b The Alderney Ox.—This breed is probably identical with the previous one. Its increased size is, perhaps, to be attributed to its having inhabited, for so many centuries, the fertile Channel islands. It has the want of symmetry characteristic of its Scandinavian origin. The milk of the Alderney cow is particularly rich in cream, and hence this kind of cow is much kept by private families. It is to this reason, probably, that we must ascribe the fact, that Alderney cows almost invariably sell for more than their real value.

c The West Highland Ox.—This is the breed found to answer best in the gneiss districts of the West Highlands. The members of it are small, with horns turning upwards at the points, the muzzle is black, they have short legs, are profusely covered with hair, usually of a black, but also of a brown colour, and they have a very distinct mane. The cows are extremely bad milkers, but the beef of this breed is in very high repute.

d The Welsh Ox.—This is another small breed, very analogous to the foregoing, and found to answer well over the Silurian system of Wales. Their flesh is in great esteem, and the cows are better milkers than the West Highlanders.

e The Polled Angus Ox.—This is a breed inhabiting the fertile red sandstone of Forfar. It is not easy to determine its origin; but by living many generations in this rich country, it has become a large and much-esteemed kind. As its name indicates, the Angus ox is without horns. Although the Angus is essentially a beef-producing animal, and valued as such, the females are very good milkers.

f The Galloway Ox.—This is the kind that seems to be adapted for living over graywacke. It is a hornless breed, the members of which are generally black in colour, with long hair, suited to the humidity of the climate, and attain a pretty considerable weight. The carcase is known in the London meat markets by the great length of its sides, and the "Galloway rib," as it is called, is a favourite. The cows are bad milkers.

g The Polled Aberdeenshire Ox.—This variety belongs to the same subdivision as the two previous ones, all of which are, perhaps, descended from a common stock. But the properties that are adapted to a granite country are developed in it. Members of it are not usually fat until four years of age, and are much liked in the London and other English markets.

h The Suffolk Ox.—This is a hornless variety. The members of it are long in reaching maturity, and take a much longer period to become ripe fat than any of the three previous ones. Consequently, for the purpose of the farmer fattening cattle, they are next to useless. But the quantity of milk the females yield is very great, and for dairy purposes they are justly esteemed.

i The Ayrshire Ox.—This breed has been produced in comparatively recent times, is of medium size, is rarely kept as a fattening stock, the young he-calves being sold for veal. The cows are remarkable for their milk-yielding qualities. When examining the animals of this variety, it is easy to trace a strong resemblance to those of the Alderney breed, from some members of which they are, in all probability, partially or entirely descended.

k The Devon Ox.—This, or, to speak more accurately, the North Devon (for, in the higher parts of the country, a breed resembling the Welsh is found), is a variety held in very great estimation in England. Females belonging to it are indeed very bad milch cows, and the ox does not fatten well, even with superior food, and a somewhat favourable climate; but the docility and strength of the latter particularly qualify them for being used as beasts of burden. As there is a possibility of this kind of oxen being more or less adapted in districts where hitherto horses only have been employed to do farm labour, this breed claims particular attention. The members of it are of a deep blood-red colour.

l The Herefordshire Ox.—This is a large breed, much esteemed by the graziers in Herefordshire. The cows are indifferent milkers.

m The Long-horned Ox.—This is an artificial variety, produced by the famous Bakewell of Dishley, who likewise produced the Leicester sheep. Upon what principles he acted is not known, inasmuch as all his operations were conducted with profound secrecy. His object was to raise a breed with as little superfluous offal and bone as possible, and with the greatest attainable facility of laying on fat. He succeeded in part but too well, for animals of his long-horned breed deposited so much fat underneath the skin, and mixed so little with the muscles, that people got tired of them, just as they are now beginning to get tired of the very fat Leicester sheep. And the once famous long-horned cattle of Dishley are now almost extinct.

n The Short-horned Ox.—This is another artificial breed, produced by Messrs. Colling, principally out of the old Teeswater. Of all oxen, the short-horned fatten earliest; and as, in addition to this, the cows are pretty good milkers, they are esteemed the best breed of any for general purposes and general localities, and are very extensively used, both pure, and for the purpose of crossing with some one of the above-mentioned breeds.

Pig.—The prolific nature of the pig, the early age at which it may be fattened, the small proportion of offal, and the wide variety of food that it can subsist upon, are very great recom-

mendations. Too often the pig is only regarded by the farmer as a consumer of waste matter; but there can be no doubt that, under suitable management, pigs may be made to pay very well, either fed upon the produce of the farm, or upon purchased food. A good many varieties of the pig exist. We may enumerate—

a The Old English Pig.—This is known by its long pendulous ears and its large size. It is long of coming to maturity, but attains a great weight. It is generally white, or white spotted with black. The sow is remarkably prolific. This is the breed that used to exist in Ireland.

b The Western Highland Pig.—This variety is little known, and, perhaps, little appreciated. It is a very small animal, with pendulous ears, of a dusky-brown colour, and is furnished with a great many bristles along the neck and spine. It is remarkably hardy, and indeed generally gets leave to find its own food.

c The Chinese Pig.—This is a small, short, and erect-eared, short-legged, hollow-backed animal, not prolific, and not hardy, but coming to maturity at a very early age. The tenderness of Chinese pigs disqualifies them for this country; but they produce a most excellent cross with the old English pig.

d The Neapolitan Pig.—This a small black-coloured pig, not hardy, and not prolific, but coming very early to maturity. Hence it has been much used in this country for crossing with the old English.

e The Berkshire Pig.—This is an improved variety of the old English, apparently crossed by the wild boar, and held in great estimation.

Other breeds of pigs are known by different names in different parts of the country; but they are all probably crosses between improved varieties of the true old English and either Chinese or Neapolitan.

Poultry.—1. *Fowls.*—We may enumerate the barnyard, the Dorking, the Poland, the Malay, and the black Spanish.

2. *Turkeys.*—There are two kinds—one dark-coloured, and the other light-coloured.

3. *Ducks.*—There is a dark-coloured, but small breed; a white, which is larger; and the Muscovy.

In practice, at least in this country, there can scarcely be said to exist more than one kind of geese, Guinea-fowls, or peacocks.

DOMESTIC MEDICINE.

CHAPTER VII.

ON THE CAUSES, THE PREVENTION, AND THE DOMESTIC TREATMENT OF THE DISEASES OF INFANCY.

A female, on acquiring possession of any rare and beautiful greenhouse plant, if she values her acquisition, and is at all interested in its health and preservation, is sure to make the most careful and minute inquiry at a gardener or florist, qualified to give the necessary advice, regarding the proper treatment required to preserve it in health, beauty, and vigour. She will ask how often it ought to be watered, how much heat and how much air is necessary, when it will need shifting into a larger flower-pot, what sort of soil is required for its healthy nutriment, and how the treatment must be varied for the different seasons—for summer, winter, &c. Nor, whenever she perceives her favourite plant beginning to droop, to part with its leaves, or in any way to assume an unhealthy appearance, will she rest satisfied with the advice of her first female visitor regarding the proper treatment for its restoration; if she has common sense, and if she values the life and health of her plant, nothing less than the professional skill of a properly qualified florist will secure her confidence; he alone it is who must know the cause of the ailment, and he alone, therefore, is capable of removing the evil, and of placing the plant in a position favourable for the recovery of its health, and for the restoration of its former beauty and bloom. Our female's lady-friends and old-women visitors pride themselves on *their* skill and experience in tending and treating their own greenhouse plants, and in the present instance are quite offended because their eagerly proffered advice is disregarded; but she very well knows that *their* plants are of that hardy and common sort which require very little attention or treatment; that the rare and delicate plants which have come into their possession have invariably become diseased, and most of them have died, all through ignorance and mismanagement; and that it is only those whose hardy constitutions enable them to live and thrive in spite of bad treatment, that ever arrive at maturity and continue in health.

The rarest, the most valuable, and the most beautiful plants have almost invariably the most tender and delicate constitutions when young, and are consequently the most difficult to rear; and the constitution of every individual species of plant is different from that of another species, requiring different soil for its food, a different amount of water, of heat, of air, &c.; and if our supposed female be a sensible and well-educated person, she will know that an individual uninstructed in floral science, ignorant of vegetable physiology, cannot, by any amount of experience, prescribe the proper treatment for each member of all the innumerable species of plants, from a knowledge of the different causes of disease to which each one is exposed; she will, therefore, very properly consign the care of her plant to the judgment and skill of a man who has made floral science the study of his life, and who can preserve, in luxuriant health and beauty, plants of the most different species, and of the most tender and opposite constitutions.

In the above instance, we have given a female credit for possessing an amount of common sense sufficient to point out the course she ought to pursue in regard to the management and treatment of a delicate greenhouse plant; but how rarely does it happen that common sense is sufficiently strong to cause the adoption of the same proper and praiseworthy course, when a female becomes possessed of a *certain plant* of a much more complex structure, vastly more difficult to understand, infinitely more tender, more liable to disease, to decay, to become stunted, and otherwise to suffer, and often to die, from mismanagement—we mean a human being!

No sooner is an infant born into the world than it is consigned to the care, in most instances, of some ignorant, and, on that account, conceited old woman, who knows no more of its proper treatment—who indeed treats it much more irrationally—than the most illiterate savage. Her experience, instead of being based on sound principles, has been derived from the absurd, barbarous, and mischievous practices of her ancestors, who considered themselves skilful managers of infants if they could bring to maturity three out of every ten—setting down the deaths of the other seven, with the utmost complacency, not to their own mismanagement, but to the inscrutable decrees of Providence!

Most people follow the dictates of nature and reason in their treatment of the young of the lower animals, from the fact that, in this instance, their religious opinions do not blind their common sense, and prevent them from availing themselves of experience and observation. Farmers, for example, carefully avoid giving their calves, their lambs, or their sucking pigs, any solid food till they arrive at a certain age, well knowing that disease, and generally death, result from the use of any other food than milk, the sole sustenance provided by nature for the young of all the mammalia. But it is not enough that a human being, generally a few minutes after birth, tells in the plainest language, by sucking instinctively at everything which is brought near its mouth, that it ought to be applied to the breast without delay;—it is not enough that the mother's breasts become turgid, painful, and frequently inflame and suppurate, from delaying the application of the child;—nor is it enough that almost every one is aware that the young of all animals whose food is milk, must be fed upon milk, and upon milk *alone*, for a certain period after birth,—in many parts of Britain the mothers and nurses of children are *still* so ignorant, so prejudiced, so misled by conceited old women, and so inattentive to proper medical advice, that, instead of applying the child to the breast a few hours after birth, as they ought to do, they persist in having it fed

for a day, for two days, and in some instances even longer, with bread, biscuit, or oatmeal, soaked or boiled in milk or water. And even after the child is applied to its mother's breast, these model-managers of infancy display an amount of ignorance scarcely credible, in not being satisfied with the abundant supply of that rich and nutritious food which a wise Providence has provided as the child's *sole* and sufficient support; they cannot be made to understand and to believe that milk—the most nutritious food in nature—*is food at all*; they look upon it, because it is liquid, as nothing but drink, and little better than cold water! They therefore continue giving their pap, their oatmeal gruel or pottage, although the mother's breasts are so full to overflowing that the child cannot sufficiently empty and relieve their turgidity; so that, if the milk does not run out of itself, it must be *drawn off* for the comfort and safety of the mother!

The consequences of such mismanagement are very soon apparent to the eye of the most superficial observer. Both the mother and child suffer. The secretion of milk, from not being thoroughly drained off, becomes diminished in quantity, and from the health of the mother being affected by its reabsorption into her system, it becomes deteriorated in quality.

The pernicious effect of such a state of things on the health of the infant, can neither be overstated nor painted in too strong colours. The very structure, size, and form of the child's stomach at this early stage of its existence, show clearly that it was never intended to contain a particle of solid food, much less to digest it. As soon as the child is fed with solid food, or anything else hurtful to its delicate and sensitive stomach, it either rejects such food by vomiting, if the stomach is strong enough to expel its obnoxious contents, or it sinks into an overpowering and unrefreshing sleep, during the continuance of which it often starts from evident pain. So well aware are many mothers and nurses of the soporific effect of solid food, that when their children are irritable and restless, annoyed with pain in the bowels, &c.—suffering from the effects of previous mismanagement—they frequently fill their stomachs with such food, for the purpose of quieting the little sufferer, of producing temporary sleep, and of ridding themselves for a time of their troublesome charge—thus aggravating the evil, and laying the sure foundation of diseases which will either hurry the victim to a premature grave, or, what is even a greater calamity, will render a prolonged life miserable.

The effect of either solid food, of improper liquid food, or even of the deteriorated milk of the mother upon the stomach of the infant, is first to produce costiveness, flatulence in the stomach and bowels, and consequent pain and griping; by-and-by the tongue becomes covered with a whitish fur, to which thirst, heat of skin, restlessness, and other symptoms of a feverish state of the system supervene; and if such improper management be persevered in without having recourse to remedies, the child will pine away and die. More frequently, however, castor-oil, manna, rhubarb, calomel, or some other medicine, is stuffed down the infant's throat soon after its health begins to be affected by the mismanagement to which it is subjected; this probably relieves it for the time, but by persevering in such a course of treatment—continuing the improper food, administering laxatives, purgatives, Godfrey's cordial, Dalby's carminative, or some other equally noxious stuff, by turns—six children out of every ten are literally *killed* during the first year of their existence; and in the constitutions of most of those who survive this period, the foundation of scrofula, of indigestion, of disease of the lungs or of the brain is laid, and when the seeds of these diseases are once sown, they are ever ready, on the application of any exciting cause, to start into the full vigour of active disease; so that a comparatively small proportion of mankind arrive at mature age. The correctness of this statement regarding the high mortality of children in towns, is abundantly proved by the "Registrar-General's Returns." In the country, and even in the less crowded, more cleanly, and airy parts of towns, the infant constitution is better able to resist the pernicious influences of mismanagement than in the close, filthy, and densely-populated parts of cities. A perusal of the "Annual Reports" of the Registrar-General for England and Wales places the fact in a very strong light, *that the ratio of infant mortality is in exact proportion* to the impurity of the air which the child breathes, to the want of proper cleanliness and out-door exercise, to improper food and clothing, and to several other circumstances, all of which operate directly and indirectly on the infant constitution. They operate *directly*, by actual exposure to these different causes of disease; and *indirectly*, through the influence of the mother's milk. It is well known to every medical practitioner, that want of sufficient exercise in the open air, improper food, breathing a close and impure atmosphere, dirty habits, &c., have so powerful an effect in diminishing the quantity, but more particularly in deteriorating the quality, of the human milk, as to be no less surprising than unaccountable to non-professional persons. How then can the health of a child be maintained, its growth matured, and its constitution invigorated by an insufficient supply of food, and that food also of bad quality? As well might we expect to fatten a bullock on stunted heath, as to expect to rear a strong and healthy human being on food derived from a vitiated source.

The age of infancy may be divided into two epochs:—

The *first* epoch includes the period of suckling, or that in which the child is fed at the breast of the mother.

The *second* epoch includes the period from the weaning of the child to the completion of the first dentition.

First Epoch.—The period during which the child is fed at the mother's breast is one of the most important, if not the most important of its whole existence, in so far as the future health of the infant depends more upon its management in this epoch than in any other of the same duration. During this period, the fate of the child as to its prolonged existence, the strength or weakness of its constitution, its predisposition to disease, and even as to the term of its natural life, is generally sealed. On its treatment during this period will depend either the liability of the infant to become a prey to the first severe attack of illness, induced by mismanagement, teething, exposure to cold, or any common epidemic; or it will acquire, by proper management, the power of resisting all these causes of disease, and sufficient strength of constitution to enable it to complete the full development of its bodily faculties; it will enter on the second epoch—the period of dentition—with comparatively little to fear, and will become the fat, plump, happy-tempered, and rosy-looking little cherub, whose round, dimpled, smiling face is a pleasure to behold.

General Management of First Epoch.—*Food.*—During the first four or five months of infant life, the stomach, as above stated, is totally unfitted for digesting any sort of food whatever but the mother's milk. So much is this the case, and so inappropriate for the healthy nourishment of the child is even the milk of animals, the quality of which most nearly resembles human milk, that scarcely one child in seven who is necessarily deprived of its natural food—the mother's milk—during this period, ever arrives at an advanced age; and probably four of that seven die in infancy. No child, then, for whose life and health we have the least regard, ought to receive one particle of food for the first four or five months of its life at least, except what it derives from the mother's breast, or, failing that, from a proper milk-nurse. By a wise provision of Providence, who evidently intended the lengthened dependence of the child upon the mother to be the means of cultivating and maturing both the parental and filial affections, healthy human milk contains the whole of the ingredients necessary for the growth and full development of all the bodily tissues and organs up to a certain period of the infant's life. At the end of this period, not only has the stomach acquired the power of digesting other food, but additional means are provided, by the growth of teeth, for chewing and preparing that food for digestion and healthy nutriment.

The above remarks are made on the supposition that the mother, or, failing her, the nurse, has a sufficient supply of milk for the child, as otherwise recourse must be had to some auxiliary; and, according to the dictates of reason and expe-

rience, this auxiliary ought to be the nearest possible in its nature and quality to the mother's milk. Asses' milk is the nearest in chemical composition to human; but good freshly-drawn cow's milk, with the addition of about one-sixth part of warm water, and a very small quantity of sugar, is the most easily procured, and perhaps as good as any.

It is of the utmost consequence, for the health and growth of the child, to feed it at the breast *only* at fixed and regular intervals from the very first. As soon as the child fills its stomach, and is raised up to enable it to expel the air which has been carried into the stomach along with the milk, it should go to sleep, and it ought not to be fed again in less than *three* hours. The usual plan is to apply the child to the breast as often as the mother's time and convenience will allow—observing no regular periods for feeding—and particularly to stuff the nipple into the infant's mouth whenever it cries, or is at all difficult to manage, although probably an interval of five minutes has not elapsed since the previous application. The consequences of this mode of treatment are, that before the digestion of the first stomachful of milk is nearly completed a second is poured in, then a third, a fourth, and so on; so that the stomach is kept constantly at work; it has no time to recover from the fatigue of digestion, and to rest; it soon, therefore, becomes overworked and weakened, and by-and-by refuses to digest at all; the child is then often and greatly pained by the griping caused by the flatulence or wind in the stomach which arises from the undigested food. It by-and-by becomes feverish, and sucks from thirst, and not from natural hunger: matters have now arrived at such a pitch, that unless the infant get a dose or two of laxative medicine it will very likely pine away and die; whereas, had it been properly managed—had it been fed at the regular and necessary intervals, and, when griping, furred tongue, and other symptoms of disordered stomach pointed out that the food is given either in improper quantity or quality, or at improper times—had its supply of milk been restricted, and had it been allowed a little cold water or barley water to drink,—we would hear of fewer drugs and nostrums for children's maladies, and of far fewer diseases and deaths in infancy and childhood.

Clothing.—It has been proved by experiment, that the bodily temperature of man, as well as of all the inferior animals, is much more easily reduced in the young than in those of mature age. A few hours' exposure would kill an infant, when no bad effect would be produced in a youth of ten or twelve. Young children, then, ought to be well protected by clothing, at least in a climate subject to such vicissitudes as that of Britain; they certainly ought not to be overloaded with clothes—a habit well known to be most pernicious and weakening both in young and grown-up persons—but their clothing ought to combine *warmth* with *lightness*, to consist chiefly of fine flannel, and especially to cover all parts of the body equally. The fashionable mode of dressing infants, and which many think on that account the best, is most pernicious and absurd. The upper part of the chest—the spot where the seeds of consumption first commence their ravages—is left nearly naked, while two or three yards of flannel are dangling uselessly far beyond the feet. Infants are very liable to inflammation of the lungs, arising from exposure to cold and insufficient clothing; it is often during the period of infancy also, that the germ of consumption is first laid in the constitution, to lurk there, ready to bud forth into fatal activity on the occurrence of a sufficiently powerful exciting cause: children, therefore, ought to have all parts of the body properly protected from the influence of cold. Although the practice is fortunately dying away, yet in many parts of Britain the head is still too much covered up, encouraging an undue determination of blood to that part; so that, when any other special cause is in operation, such as teething, &c., it is apt to produce inflammation of the brain and its membranes, ending in the disease popularly termed "water in the head."

A discrepancy of opinion exists with regard to the propriety of children wearing flannel next the skin; but there can be no doubt that, by the healthy amount of friction which it produces, causing a determination of blood to the skin, and thus relieving the internal organs—by its absorbing the sensible perspiration and all other moisture from the surface of the body—and by its agreeable warmth, flannel ought to be worn next the skin.*

Cleanliness.—For the sake of cleanliness, and to promote the healthy action of the skin, every infant ought to have its whole body sponged with soap and water twice every day—in the morning, at first with lukewarm water, gradually reducing the temperature as the age advances, till the child has sufficient strength to bear it cold; and at night with tepid water, without reducing the temperature. The operation of sponging should be performed in a warm room, as expeditiously as possible, after which the child should be dried quickly, and then well rubbed over with a coarse towel or a soft fleshglove, followed by friction over all the body with the palm of the hand. Nothing can be more beneficial for the health, and bracing for the constitution, than cold sponging in the morning, if quickly and properly done, and if it is succeeded by sufficient friction to produce reaction. The great object is to give the body such a sudden shock of cold as to be followed by a perceptible warm glow of heat, from the rapid determination of blood to the external surface of the body. By this means an equal distribution of blood over the whole frame is maintained, and inflammations of internal organs, consumption, colds, &c., are thereby prevented.

Sleep.—The hour of going to sleep should be as regular and fixed as the hour of giving the breast. The children of the poor, who are, and in some cases must be, irregularly fed, and made to sleep a great deal too much, labour under very great disadvantages. The mother has her work to do, and if there are other children, she has them also to attend to; she has therefore the greatest difficulty, even were she so inclined, in fixing regular hours for feeding her infant and putting it to sleep. A great deal, however, might be done even by the very poorest, if they could be made to understand the urgent necessity of adhering to fixed rules; and were they to begin, from the very birth of the infant, by feeding it and putting it to sleep at regular intervals of three hours, they would soon find not only that their *time* would be greatly economised, but that their own comfort and that of their children would be materially increased.

Every mother ought to have her attention pressingly called to the fact, that irregularity in feeding her infant and putting it to sleep very soon brings on indigestion, griping in the bowels, wasting of body, fretfulness of disposition, and, in short, all the diseases incident to children, in a markedly aggravated form.

Air and Exercise.—Unless it is wished to make human beings resemble hothouse plants, to have them blanched, drawn up, and fragile, and to have the age of decrepitude brought on at a time when they should be still in the prime and vigour of life, children ought not only to have dry, well-aired, and, if possible, large and lofty rooms for nurseries, but they should also, at a very early age, be gradually inured to bear the cold air out of doors. The larger, more cool, and better aired the nursery, the less will be the risk of the child suffering from exposure to cold, the stronger will be the constitution, and the less subject to those diseases which arise from the effects of cold. An infant ought to be accustomed to the open air from the age of two, three, or four weeks, according to the constitution of the child and the season of the year; at first only for a few minutes, but, unless the weather be very bad, it ought to be well wrapped up, and carried out for a short time every day, as much to benefit by the benign influence of the rays of the sun, which is so essential to the growth and health of both plants and animals, as to participate in the bracing effects of pure atmospheric air. Children who are properly managed, who undergo systematic sponging with cold water every morning, followed by friction, and who are properly wrapped up when carried out, rarely suffer from the bad effects of cold, unless the exposure be protracted beyond the proper time.

* It is a well-ascertained fact, that before the use of flax or cotton, consumption was proportionally a much more rare disease among our forefathers than it is now.

Indispensable, however, as the fresh open air is to the infant, it is so to the mother or wet nurse *in a tenfold degree.* If it were wished to produce milk of the worst quality, deficient in nutritive properties, and otherwise hurtful to the stomach and infant constitution, no more effectual plan could be adopted for such a purpose than to debar a wet nurse from taking daily exercise in the open air, to confine her to small ill-ventilated rooms, and to attempt to keep up her strength by wine, porter, and other such stimulants, instead of keeping her health up to a maximum of vigour by sufficient exercise in the open air in all sorts of weather, good nourishing food, proper attention to the state of the bowels, to cleanliness, proper clothing, &c.

If a child is in a healthy thriving state, it will begin, in the course of two or three months, or even less, to show symptoms of a desire for bodily exercise—of a wish to use its arms and legs; and that female deserves the name of an indolent, slothful, ignorant, and even *cruel* nurse, who refuses to gratify this desire. In a healthy state of the system, the quicker the blood circulates the more rapidly does the growth proceed. Exercise sets the blood in quick circulation, and the Creator has therefore implanted in the young of all animals an irresistible desire to exercise their whole muscular systems—exhibiting itself in the playful gambols of the kitten, the frisking and frolicking of the puppy, the racing and leaping of the lamb, the graceful gallop of the colt, and the merry dance of the infant on its mother's knee. To restrain a child, therefore, in its cheerful plays, its artless tricks, and its restless activity, is to give way to laziness or ignorance, and to counteract one of the wisest and most indispensable provisions of the Deity for the health and growth of the infant frame.

Diseases Incident to the First Epoch.—*Costiveness.*—If the child has been applied to the breast sufficiently early, and no other food but its mother's milk has been administered, the new milk, being of a different quality, and having different properties from milk a few days old, has a laxative effect upon the bowels, and medicine, which ought, if possible, to be avoided, is rarely necessary. But if, from any unavoidable cause, the child's bowels are obstructed after birth, so as to retain a portion of the *meconium*, or dark tarry-looking stuff which collects in the intestines before the child is born, a little powdered rhubarb or a teaspoonful of castor-oil must be given, probably oftener than once, till the fæces assume a natural yellow colour. If the bowels become costive afterwards, we may rest assured that there is some error in the management either of the child or of the mother. This ought to be discovered and rectified; and, till then, a little castor-oil or compound rhubarb powder ought to be administered every day, or every alternate day, till the bowels get into proper order.

Griping.—This is a name given to fits or paroxysms of pain in the stomach or bowels, and always arises from mismanagement—generally either from improper food, from the mother's milk being deteriorated in quality, from irregularity in the times of giving the breast, or from exposure to cold. The proper cure, in every case of disease, is first to remove the cause, and if the cause of griping be removed, nothing but a little of the above-mentioned laxative medicine will be found necessary.

Redness and Inflammation of the Eyes.—This arises either from carelessness in washing and bathing the eyes immediately after birth, or from exposure to the strong light of a candle, gas, or the heat of a fire. By these strong lights acting as powerful stimuli on the delicate eyes of new-born infants, inflammation and loss of vision are frequent consequences. After the child's body has been thoroughly washed with soap and warm water, as soon as possible after birth, and the clothes put on, the face, and particularly the eyes, ought to be well bathed with clean warm water, without soap, by means of a very soft sponge, or piece of fine linen.

Red Gum, or Red Gown, called also, when it appears in children during teething, *Tooth Rash.*—This is an eruption of small reddish pimples on the skin, often appearing over the greater part of the body in children a few days old. It is so common in many parts of Scotland, where it is called the *Red* or *Yellow Gum*, according to the colour of the skin, that nurses look for it as something indispensable to the health of the child; so ignorant are they as to its real nature and cause, or that it is a disease of their own creating. It is always accompanied with furred tongue, more or less feverishness, and other symptoms of disordered stomach; it arises solely from mismanagement, from loading the stomach with indigestible and improper food, producing irritation in the bowels, looseness, vomiting, &c.

This complaint seldom requires much treatment, farther than rectifying the error of management, stopping the supply of every sort of food except the mother's milk, giving even that in restricted quantity, till the stomach recover its tone, and administering a little of the above-mentioned laxative medicine.

Inflammation of the Chest.—Under this head we comprehend what is technically called *pneumonia*, or inflammation of the substance of the lungs; *pleurisy*, or inflammation of the membrane in which the lungs are imbedded; and *bronchitis*, or inflammation of the air-tubes leading to the lungs. These inflammations are far more common in infancy, are more frequently either immediately fatal, or—by impairing the efficacy of the respiratory organs for life, and by leaving them an easy prey to future attacks of disease—leave indelible traces of their ravages to a much greater extent than non-professional persons can imagine, or than even most medical men are aware of. Inflammations of the chest cut off nearly a third of all the children who die within the first year of their life; and are the remote causes of death in many more who die afterwards, from their baneful effects in causing the supervention of other diseases, but who survive, perhaps for a year or two, the first acute attack of the inflammation.

These inflammations are ushered in by a smart attack of fever. They begin by a cold shivering all over the child's body—the skin becomes pale—the countenance changeable, but generally pale and sunken—the lips purplish—and a total disinclination to food. To these symptoms, in a few hours, succeed burning heat of skin, flushed countenance, incessant thirst, the pulse very quick, a peculiar brightness of the eyes, and the breathing hurried and anxious, sometimes accompanied by a short dry cough, but not so much as to attract particular notice. In such a state of things, no time should be lost in giving the child a warm-water or steam bath; the whole body of the child, except the head and face, ought to be covered with water as warm as the skin can comfortably bear, for about ten minutes. It should then be well dried, and rubbed over with a warm towel, rolled up in a large piece of hot flannel, and put to bed. A powder, composed of half a grain of calomel and two grains of James's powder, should then be immediately administered, to be followed in four hours by a smart dose of senna infusion. If the symptoms of fever and inflammation do not subside after the operation of the purgative medicine, a medieal practitioner ought to be immediately sent for.

Teething.—If an infant is at all properly managed—if it derives a sufficient supply of healthy milk from its mother or nurse—if its hours of feeding and sleep are fixed and regular—if its clothing, cleanliness, air and exercise are adapted to the age of the child and the season of the year—and if all the principles already laid down regarding its general management are punctually attended to, the complaints of children are generally very few and very simple till the period of teething commences. And although this period be looked upon by mothers as one of peculiar anxiety and solicitude on behalf of their offspring, yet, if they have been guided by these principles of management, there is seldom much to dread. If, on the other hand, the child, as is but too often the case, has been mismanaged in regard to diet, sleep, clothing, cleanliness, air and exercise, the mother is not anxious without reason, nor solicitous without ample grounds.

A month or two before any of the teeth make their appearance, the child often exhibits symptoms of slight feverishness; it has some degree of thirst, heat of skin, and restlessness, particularly during the night; the saliva runs from its mouth; costiveness, but more frequently looseness,

prevails; the happy, cheerful, and contented expression of the child gives place to irritability of temper, to fretfulness, and an appearance of dissatisfaction quite new to it; the plumpness and firmness of its flesh are exchanged for paleness, softness, and flabbiness; and altogether the infant assumes an unhealthy aspect. The irritation produced in the gums by teething, gives rise, in unhealthy and ill-managed children, to a morbid excitability in the brain and its membranes, originating a predisposition to inflammation, which, in its turn, induces convulsions, high fever, delirium, water in the head, &c.; and, unless actively treated in the commencement, death is the general termination of such a case.

The treatment of all the serious disorders connected with teething, ought to be entirely consigned to the care of the family medical attendant; the great duty of mothers *not* being to cure their children when they become really ill, but, by attentive, enlightened, and skilful management, to ward off disease, and to endeavour, by every means in their power, to prevent its occurrence. It must be carefully borne in mind, that *costiveness*, during teething, must be very scrupulously guarded against, from its being the cause of inducing many serious disorders; whereas *looseness* is often an effort of nature, established to relieve the system of some irritating matter, and to carry off that tendency to plethora and over-fullness of blood, and that disposition to fever and inflammatory disease, which, at that period, is so markedly present. Looseness, then, if not too severe and too long protracted, has a salutary effect on the system, prevents many worse evils, and ought not to be rashly checked or interfered with, unless by the express orders and under the superintendence of a medical man.

If the child loses its appetite, becomes languid, dejected, and wasted in flesh, with a feverish state of the system at night, it ought to be bathed in warm water every alternate night at bedtime; to have a powder, composed of two grains of Dover's powder and three grains of grey powder, every night, followed next morning by such a quantity of compound rhubarb powder, or rhubarb mixture, as will be sufficient to act two or three times on the bowels.

The complaints most to be dreaded during teething, are inflammatory affections of the brain and its membranes; the symptoms of which are, convulsions, vomiting of everything liquid or solid which is taken into the stomach, loss of appetite, thirst, heat of skin, particularly of the head, and other signs of fever, accompanied with an unnatural throbbing or pulsating at the opening of the bones of the head, called technically the *anterior fontanelle*. These symptoms point to the brain as the seat of disease, and absolutely demand instant medical treatment.

For the prevention of inflammatory affections of the brain, which are popularly termed *water in the head*, all the rules of management above laid down must be carefully attended to, more especially with children living in towns, where these diseases are far more common than in the country. The head ought to be kept cool, and be frequently sponged with cold water; the feet and legs should be kept warm; the state of the stomach and bowels should be sedulously watched, and costiveness, in particular, ought never to be allowed to continue; the whole body should be sponged every morning with cold, and every night with tepid water, using a little soap; but if the bowels are in a relaxed state, and loose stools passed five or six times during the twenty-four hours, cold water must on no account be applied to the skin. The times of feeding the child at the breast, and of putting it to sleep, must be fixed and regular; both it and the mother ought to be exposed to the open air, by taking a regular walk every day; the room in which they live ought to be large and airy, and, above all, *be kept perfectly clean and thoroughly ventilated.*

It is often of great consequence, in preventing many of the disorders arising from teething, and in relieving the pain and irritation attending that process, to have the gums frequently and well scarified, when the rounded swelling, heat, and tenderness of the parts show that the teeth are approaching the surface. Scarification of the gums ought never to be objected to, as it very often is by ignorant mothers, since it very generally affords the child great relief, and, when properly done by a medical man, can never be productive of harm.

Many children are annoyed by eruptions and rashes on the skin during teething, constituting what was already mentioned as the *tooth rash;* these eruptions are produced by derangements of the stomach and bowels, to the state of which, and not external applications to these disorders, all remedial treatment ought to be directed. Eruptions at this period, although unsightly and somewhat troublesome in themselves, are rather salutary than otherwise, having a tendency, by way of counter-irritation, to relieve the internal organs from the many complaints to which they are liable.

THE ELECTROTYPE.

CHAPTER V.

DIFFERENT FORMS OF BATTERY—BEST POSITION OF MEDAL.

In an elementary treatise on electro-metallurgy, it is unnecessary to describe every form of battery that has from time to time been brought before the public; and as several of these have already been described in this work (vol. i., pp. 189, 277), we shall notice those only which are most commonly used in the processes of electro-metallurgy.

In last article, we alluded to the most elementary form of a galvanic battery, namely, the immersion in acidulated water of a piece of zinc and a piece of copper in contact. It is not necessary, however, that the two metals be those which we have specified; nearly any two metals, under similar circumstances, will excite a current of electricity, though the current will be of variable strength, according to the nature and properties of the two metals employed. To have any effective electrical power, it is necessary that one of the metals employed be capable of combining easily with the elements of the solution in which they are placed, while the other does not; and the power obtained, under proper circumstances, has an intimate relation with these two properties in contrast. The metal which undergoes solution is termed the positive metal, the other the negative metal. Metals are not considered to possess any intrinsic negative or positive principle; their relations in this respect are governed solely by the circumstances in which they may be placed. For instance, if we connect a piece of copper and a piece of iron, and immerse them in acidulated water, the iron is dissolved, and is positive in relation to the copper; but if the same metals are immersed into a solution of yellow hydro-sulphuret of potassium, the copper is dissolved, and is positive relatively to the iron. Hence, to obtain a galvanic battery, the conditions are simply to provide two metals, and immerse them in contact in a solution capable of acting upon the one, and not upon the other. The following table shows the order in which the common metals stand to each other, in respect of their relative negative and positive properties, when immersed in water acidulated with sulphuric or muriatic acid, the most intensely negative metal standing highest, and the metal which acts most positively standing lowest:—

Platinum.	Nickel.	Iron
Gold.	Bismuth.	Tin.
Antimony.	Copper.	Cadmium.
Silver.	Lead.	Zinc.

According to this arrangement, each metal is positive with respect to all that stand before it, and the electrical conditions of any pair become the more contrasted the further apart they stand in the scale. Thus, a battery composed of zinc and platinum is much more powerful than one composed of zinc and copper; and again, copper and iron make a very weak battery.

A battery may also be formed by having one metal and two kinds of solutions, separated by a porous diaphragm. For

example, we may have strong nitric acid into one division, and dilute sulphuric or muriatic acid into the other; and by putting into each a piece of clean iron, a powerful current is obtained. These, and several other arrangements of solutions and metals, are expensive, and troublesome to keep in order, and are therefore never used for practical purposes in the art of electro-metallurgy. For this reason, we will not enter further upon their detail in this paper.

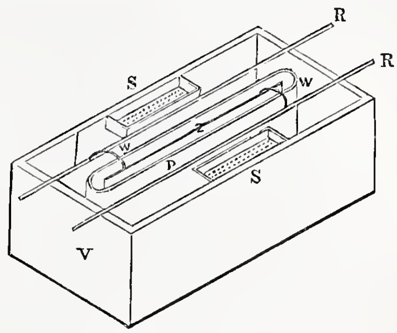
It was stated in last article, that when two metals are immersed in an acid solution, they do not form a battery until they are brought into contact, immediately after which chemical action takes place. These phenomena may be thus explained:—Let the metals employed be zinc and copper, connected by a copper wire, and immersed in dilute muriatic acid; the zinc is immediately acted upon, while a flow of gas rises from the surface of the copper. Now, muriatic acid is composed of chlorine and hydrogen; the chlorine is highly negative, and the hydrogen is positive, and these circumstances are the original cause of their combining to form muriatic acid: but when the zinc and copper are connected, the zinc becomes more positive than the hydrogen, and the copper more negative than the chlorine, and hence the chlorine is attracted to the zinc, and the hydrogen to the copper. Decomposition of the acid ensues, and the chlorine combines with the zinc, and forms chloride of zinc, which is dissolved in the water; and the hydrogen, not being able to combine with the copper, is evolved from the surface in the form of gas. During this action, electricity passes through the solution from the zinc to the copper, whence it is reconducted to the zinc by the connecting wire, to restore the equilibrium.

If, instead of immersing these two metals in dilute acids, they be immersed in a solution of a metallic salt, say the chloride of copper, which is a combination of chlorine and copper, the same kind of action takes place; the chlorine combining with the zinc, and the copper uniting to the copper plate. The electrotype is thus formed; though, if this plan were adopted, good electrotypes would not be produced, as the zinc would soon be coated with a precipitate of copper, resulting from a chemical action between it and the solution. Thus two surfaces of copper would oppose each other, and consequently little or no galvanic action would ensue. This difficulty is obviated by procuring a porous vessel, into which is poured a little dilute acid, or a solution of sal-ammoniac or of common salt. Into this vessel is placed separately the plate of zinc; the vessel and its contents being then placed in the copper solution, and maintaining the two separate liquids at nearly the same height, the metals are connected, and the action proceeds as already described.

Various materials have been recommended for porous diaphragms, among which are bladder, thin sycamore wood, stout canvas, and biscuit pottery. Mr. Mullin's wooden partition is strongly recommended in the chapter on "Voltaic Diaphragms," (vol. i., p. 369); but, from our own experience, we give the preference to biscuit or unglazed earthenware. Indeed, for small electrotype operations, we have found the common garden pot to be as good as any other material we have tried; but where a porous vessel may not be conveniently had, the zinc may be wrapped in two folds of stout brown paper, provided there be no holes nor joinings through which the solution may enter. The zinc is then connected with the mould to be deposited upon, and they are immersed together in the copper solution. This forms an excellent substitute for a porous cell, and may be used conveniently in vessels of any form.

The first step in preparing electrotypes, is to prepare the solution. For this purpose, sulphate of copper is best, crystals of this salt being dissolved in cold water to saturation, and a few drops of sulphuric acid ought to be added to the solution. The porous vessel being filled with a weak solution of salt and water, or water slightly acidulated with sulphuric acid, it is placed in the copper solution. The mould being now connected by a copper wire with a plate of amalgamated zinc, the zinc is placed in the solution of salt, and the mould in the copper solution, facing the zinc plate. Care should be taken that the portion of the zinc immersed in the liquid in the porous vessel should have some relation to the size of the mould, otherwise the copper deposited will be either crystalline, or in the state of a gritty powder. On account of the deposition of the copper upon the mould, the solution would very soon become exhausted, and require renovation. For this purpose, a quantity of crystals of the sulphate of copper must be suspended at the surface of the solution, placed either on a shelf, or in a small cloth bag; these are dissolved as the solution requires them, and they by this means maintain it in a proper working condition.

Various arrangements, having economy principally in view, have been proposed and adopted for producing electrotypes upon this principle. The most economical, and also the best, which we have seen, is a modification of Daniell's battery, and is shown in the following figure.



v is the external vessel, commonly made of glazed earthenware, which may be of any convenient depth; s s are two perforated box-shelves, fixed inside to hold crystals; p, the porous cell, in which is placed, z, the zinc plate; r r are two brass rods laid over the vessel; w w, wires connecting the zinc plate with the brass rods. A vessel of the dimensions, 8 inches by 12, by 8 inches deep, is well adapted for electrotyping.* With one of these, a number of medals may be done at once; they have only to be suspended by a copper wire from one or both of the brass rods, as both surfaces of the zinc are effective. The whole becomes a very economical arrangement, and is termed the single-cell process. Indeed, a very simple apparatus, for small operations, may be made by using a common tumbler or jelly-pot for the outer vessel, and an ordinary lamp-glass, with a membrane of bladder tied round its lower end, for the porous vessel. The latter, containing the acidulated water, is placed or suspended in the former, containing the sulphate of copper.

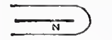
In referring again to what we stated as necessary to the formation of a galvanic battery—that the two metals be in contact, it is not essential that this connection be completed with metal: a liquid may be employed. For instance, if zinc and copper be immersed in an acid, as described, and the wire which connects them be broken in the middle, and if each end be introduced into another vessel containing sulphuric acid and water, the current of electricity will pass through that liquid as it did through the wire, with this difference, that the liquid is decomposed by the passage of the current. It will be observed, that if this connecting liquid be composed of sulphate of copper, instead of sulphuric acid, and at the end of the wire attached to the zinc of the battery there be suspended a silver coin, and at the other wire a piece of copper, the decomposition of the liquid will be as follows: the copper plate in this cell is the positive pole, and the silver coin is the negative pole; hence the copper is liberated at the silver coin, forming a plate of copper the exact counterpart of the coin, and the sulphuric acid will pass to the copper pole, with which it combines, so that a portion of copper is dissolved exactly proportional to the amount of copper deposited upon the coin, and the solution is maintained in one state—hence there is no necessity for hanging crystals of sulphate of copper in this solution. This is one of the chief reasons for preferring the battery to the single-cell process. Besides, by using common acid batteries, the expense and inconvenience of porous vessels are dispensed with. Any

* It may be had from any of the makers of galvanic apparatus.

kind of battery may be used to effect the object just described; but in small operations there is none better than Daniell's, for which see our last chapter on this subject, and also vol. i., pp. 277, 369. The only objection to this battery is its expense; but the single-cell battery described above may be made to act like Daniell's battery, and produce a second set of electrotypes in a separate cell; as, for instance, if the two brass rods shown in the figure above, be placed over another vessel containing sulphate of copper, to the one rod is suspended in the solution a piece of copper, and to the other a few moulds—the wire from the zinc in the porous cell is attached to the rod which has the moulds, the wire from the moulds in v are attached to the brass rod holding the copper plate. This arrangement was suggested by Mr. Mason, as described in last chapter.

The most common kind of battery is composed of zinc and copper, immersed in dilute acid, but the manner in which they are arranged is of considerable consequence.

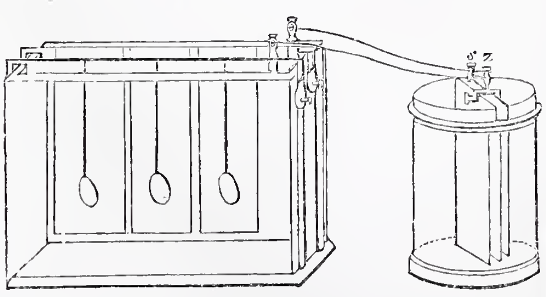
The best arrangement we have tried, is to cut a plate of copper in this shape; the piece cut out at s, is left attached at the one end, for the purpose of making compound arrangements to be afterwards described. This plate is bent thus,



and a piece of zinc, z, is placed between, so that both surfaces of zinc are exposed to the copper, producing a great amount of electricity. These may be fixed into any convenient vessel, filled with sulphuric acid diluted with twenty-five times its volume of water; a wire being attached to each, may be connected with moulds and sheet copper, to produce electrotypes as above described.

Where neither copper nor zinc can be conveniently procured, a good substitute may be found in iron. If a sheet of iron be cut as shown above, washed over with a little dilute acid, and exposed to the air until it is completely covered with red rust, it will serve as a substitute for the copper; then, by substituting a piece of clean iron for the zinc, we have a good and cheap battery for electrotyping. The necessary precautions are, to keep the one always red-rusted, the other as clean as possible.

A modification of the acid battery, as it is termed, has been introduced by Mr. Smee, hence called Smee's battery. In the ordinary battery, the current is interrupted by hydrogen adhering to the surface of the copper plate, and the smoother the plate the greater liability to this defect. To obviate this, Mr. Smee deposits platinum in a finely divided state on a sheet of silver, which produces an infinity of minute points; this facilitates the evolution of the hydrogen. The deposit is effected by using a dilute solution of nitro-muriate of platinum, instead of sulphate of copper. "The silver to be prepared for this," says Mr. Smee, "should be of a thickness sufficient to carry the current of electricity, and should be roughened by brushing it over with a little strong nitric acid, so that a frosted appearance is obtained. It is then washed, and placed in a vessel with dilute sulphuric acid, to which a few drops of nitro-muriate of platinum have been added. A porous tube is then placed into this vessel, with a few drops of diluted sulphuric acid; into this the zinc is put. Contact being made, the platinum will, in a few seconds, be thrown down upon the



surface of the silver as a black metallic powder. The operation is now completed, and the platinized silver ready for use." The platinized silver is generally placed between two zinc plates, as in the preceding figure, where *s* is the silver plate, connected with the copper of the usual decomposition cell, and *z* the zinc plate connected with the moulds. Care must be taken to avoid dropping any sulphate of copper into the acid water. This battery is well adapted for small operations in electrotyping, but it has some disadvantages, which tend to prevent or limit its adoption in the practical operations of electro-metallurgy on a large scale.

These are the batteries most generally used in the art of electro-metallurgy; the method of producing great power in overcoming resistances which occur with some of the metals, will be detailed in our next.

When our object is the multiplication of medals and similar objects on a small scale, a Daniell's battery may be made to serve the double purpose of a battery and positive electrode in the decomposition cells. Thus, if the battery be placed into a small earthenware pan, such as a jelly-can, filled with a solution of sulphate of copper, the medals have merely to be attached to the zinc of the battery, and hung round the outside of the copper cylinder in the solution of sulphate of copper. The cylinder serves the purpose of the positive electrode. Six or more medals may be suspended round the cylinder, attached to the same zinc; and if care be taken to add sulphate of copper to the battery in proper quantity, the copper cylinder will receive a coating inside, just in proportion to that dissolved from the outside by the deposition on the medals.

A question often suggests itself to the electrotypist, What is the best position in which a medal should be hung in the solution? Convenience has brought into general practice the suspending of it perpendicularly in the solution, having the positive electrode or pole facing it in a parallel direction; but to this method there are some objections. If, for instance, the porous diaphragm, or single-cell system, be used for obtaining the medals, it is found that upon the lower portion of the medal the deposition is much thicker than upon the upper portion. Indeed, when even ordinary attention is not paid, the lower part becomes not only thicker, but studded over with round globules of copper, or with lines composed of these globules, while the upper part remains thin, and is covered over with what is termed the sandy deposit copper, in dark brown grain, capable of being rubbed off with the slightest friction. No doubt this is in a great measure prevented by agitating the solution; but it is inconvenient, and requires constant attendance.

If a separate battery be used, and the deposition of the medal effected in a separate vessel, by having a copper positive electrode, the same inconvenience takes place to a greater or less extent, according to the distance at which the two poles are placed. These inconveniences are known to all electrotypists, and the cause is ascribed to the different densities of the solution. The reason why the solution becomes of different densities, is easily understood in the single-cell process: there being no copper pole to maintain the strength of the solution, as it becomes exhausted of copper by the deposition, the lighter portion floats on the top, and the heavier portion remains below; and although crystals of sulphate of copper be suspended in the solution, as they dissolve they sink by their gravity, and cause a flow upon the lower portion of the medal, and consequently a much more powerful deposit. But why the same should take place with a separate battery, where there is a positive electrode of copper being dissolved, just in proportion to the copper extracted from the solution by the medals, is not so well known; but in the summer of 1844, a paper was submitted to the Royal Society of London, by Professor Daniell, and another to the Chemical Society of London, by Mr. James Napier, upon certain phenomena exhibited during the decomposition of metallic salts by a galvanic current. Among other phenomena, the authors remarked, that during the deposition of metal, say copper, in electrotyping, the acid, when exhausted of the copper at the surface of the medal, is transferred to the positive pole, and dissolves a portion of copper; but this portion is not transferred by the electric current to the medal—hence it will be observed, that the solution next the medal will become exhausted of copper, and will consequently rise to the surface from its greater lightness. There is, no doubt, a flow of stronger solution in a horizontal direction,

from the positive pole to the medal, caused by the lighter portion ascending. But this does not mend the evil; the light portion is increasing on the surface, and the whole solution soon becomes of different densities, from the surface to the bottom of the medal; and this constant current of the solution flowing up to the surface upon which the electrotypist is depositing, causes the lines often observed in deposits under certain circumstances, and which are attributed by Mr. Smee to the ascending current of hydrogen.

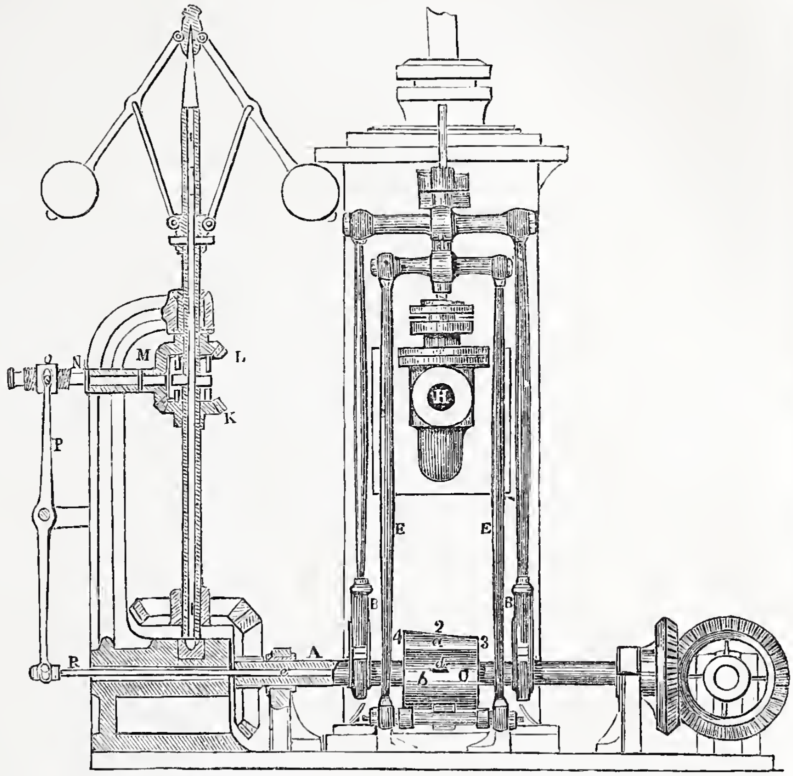
From these observations, the reader will now be able to answer the question, What is the best position to place a medal in the solution? To make it still more apparent, take a glass jar, filled with a solution of sulphate of copper; place a piece of copper upon the bottom of the jar, and suspend the medal at the top, having their two faces parallel; connect them with a battery; in a short time the solution round the medal becomes exhausted, and even colourless, the medal covered with a dirty-brown powder, and no further deposit will take place, although the battery were kept in action for weeks. But reverse the case: place the medal at the bottom, and the copper positive electrode at the top; the deposition goes on constant and smooth—the solution is maintained in the same condition as it was at the first, there being a constant transfer—the acid is transposed by the current from the medal to the copper pole—the sulphate of copper formed descends by its gravity to the medal. There are, no doubt, a few slight objections to placing the medal under the positive electrode—such as the impurities in the copper getting disintegrated, and falling upon the surface—but a piece of cloth wrapped round the pole prevents this. However, when a fine surface is wanted, care ought always to be taken to have clean solutions filtered and kept covered from dust; and when the single cell is used, the crystals of sulphate of copper should be suspended in a fine linen bag, or the shelf holding them lined with linen.

ORTLIEB'S CUT-OFF FOR STEAM-ENGINES.

Mr. Frederick Ortlieb, of Duchess County, New York, has invented an improved cut-off, for operating the valves of steam-engines, of which the accompanying engravings will enable us to explain the mechanism. The chief novelty of this invention consists in the employment of a peculiar cam, which is placed on the shaft that operates the slide-valve, or by placing the said cam upon an independent shaft to operate the valve. The arrangement is somewhat complex, but will be understood by reference to the annexed engravings.

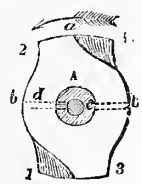
Fig. 1 is a front elevation of the machinery; fig 2 exhibits one end of the cam, and the opposite end is shown in fig. 3, which is a part sectional elevation. A, is the way-shaft, which is intended to be driven at the same speed as the main shaft of the engine; the way-shaft, A, carries the eccentrics, B, B, to which are connected the rods, E, E, and to these is attached the cross-head of the valve-rod. C, is the cut-off cam, which constitutes the principal feature of the improvement; it is in the form of a cylinder, having two diameters. The parts, *a*, *a*, may be considered as portions of a cylinder having the greater diameter, and are parallel with each other longitudinally, and with the axis. These parts form toes, one edge, 1, of each being straight and parallel with the axis, while the other, 2, runs spirally. The least

Fig. 1.



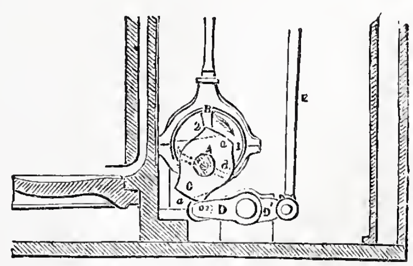
prominent parts, *b*, *b*, are likewise parallel with each other and with the axis, and the form which is thus given to the cam is distinctly shown by the end views in figs. 2 and 3. The cam operates on a roller connected with the valve-rod, and the ascent and descent to and from the projecting parts, *a*, *a*, is made as sudden as is consistent with that movement. The cam fits easily on the shaft, A, and its form is the same throughout its whole length.

Fig 2.



A narrow slot, *c*, is cut through the shaft, A, its length being nearly equal to that of the cam, and a key-way is cut diametrically through the cam, which passes freely through the slot, *c*, but is fixed firmly in the cam. The use of this key is to prevent the cam from turning on the shaft, while it allows the former to slide longitudinally along the slot. The shaft is bored to be tubular for a great portion of its length, and into the bore of the shaft is fitted a small rod, *e*, secured to the cam by the key, *d*, which passes through it. By drawing or pushing this rod longitudinally, the cam is made to slide backwards and forwards on the shaft; and it is by this action that the cam is made to actuate the valve-rod, to make it cut off the steam with a shorter or longer stroke, according to the velocity of the

Fig. 3.



governor. P, is a lever connected to the rod, R, or *e*, by an eye hooked over a pin at the foot, and this lever is secured on a fulcrum-pin at the centre. N, is a revolving spindle, with a bevil-pinion, M, on its inner end, and a screw or thread, O, cut at its outer extremity. At the top of the lever, P, is a pin, the inner end of which fits into the threads of the screw, so that, according to the direction in which the spindle, N, is made to revolve, the screw will draw in or work outwards the upper end of the lever, P, producing a reverse motion of its lower end, by which the rod, R, is made to draw the cam to the left or to the right; and by this oscillatory movement of the cam, a smaller or greater surface of the toes, *a*, *a*, is made to act on the roller of the valve-rod (as shown in fig. 3), to cut off quicker or not, as the case may be. This movement is directed by the governor, on the common sliding collar of which there is a bevil-pinion, K, at the foot, and another, L, farther up. It will be observed that there are two pins standing up on the inside of the pinion, K, and two projecting down from the one, L, as also a cross-pin on the spindle of the governor between them.

The fixed action of the governor and spindle is shown in fig. 1, and the cross-pin on the spindle of the former is now revolving between the bevil pinions. If, however, the velocity of the governor were increased, the slide-collar would be drawn up, so that the pins of the lower pinion, K, would be caught by the cross-pin on the vertical spindle, and then the two pinions, M and K, would mesh, communicating motion immediately to the spindle, N; the screw would now act upon the pin of the lever, P, drawing in the upper end of the lever, thereby thrusting out its lower end, and drawing the cam-rod, R, with its cam further out, so as to bring the smaller toe-surface to act upon the roller of the vibrating valve-lever, D, D, E, and thus cut off quicker, according to the accelerated velocity of the governor beyond the ordinary speed, so as to bring back the engine rapidly to the standard speed. When the velocity of the governor falls below the average speed, the slide of it drops, and the bevil-pinion is depressed, producing a contrary motion in the spindle, N, and thrusting in the cam, by which the valve-rod, D, D, E, is made to give the cylinder a greater quantity of steam.

It is the intention of the inventor to apply this mechanism to the puppet-valve, but not limit it to this application. By reference to fig. 2, it will be observed that the spiral line of the cam is so set out, that the narrowest ends, 3, 3, of the faces of the toes shall bear just such a proportion to the half of the circumference of the cam as it is desired that the shortest portions of the stroke of the piston under full steam shall bear to the entire stroke, say one-eighth; and that the widest parts, 4, 4, shall bear the same proportion as the longest part of the stroke, say one-half. By this arrangement the steam will be cut off at one-eighth at one end, and one-half at the other.

CONNECTION OF SCIENCE AND INDUSTRY.

Metaphysicans have laboured to show, that the present world, with its good and evil, is the best possible; and we are sufficiently imbued with the spirit of optimism to recognise the lineaments of truth in the physical applications of the doctrine. We covet superior knowledge, and pay homage to intellectual greatness; we advocate the diffusion of useful information, and hope for an educational millennium; but withal, it is not to be wished that we should merge our diversity of character in a monotonous illumination, and become philosophers of one order, however high in the scale of intelligence. A community of philosophers could not hold together; and should it ever come to pass by any miracle, that the population of our globe shall aspire to that character, it will not be difficult to predict the period of its consummation.

For the physical well-being of society, and especially for its progress in the industrial arts, two distinct orders of mind are essentially requisite. Labour is the radical element in the social economy; but labour without a guiding intelligence could make no advance, and would at most furnish only a rude subsistence. To produce its full and beneficial effect it must co-operate with mind as the directing power, and be regulated by it as its principle of action. Its true position and importance are thus defined in relation to the interest which it subserves, in terms which bear a striking analogy to the functions performed by the muscular and nervous systems in the animal organization. But while intelligence is necessary to the government of the labouring force; and while, with a given amount of this directoral agency, a definite condition of society, with respect to physical comfort, might be maintained; something more is requisite to ensure compliance with those ever increasing demands for new comforts, and new conveniences, which have marked the history of the human family from the breaking dawn of fugitive tradition down to the present moment. Improvement and change give life to our social compact; stagnation is death. But improvement is the result of the growth and accumulation of knowledge—the evidence of extended acquaintance with physical truth. In this we acknowledge the utility, nay, the necessity of that order of intellect, which, looking beyond the administration of known laws, and the more practical pursuits of everyday life, seeks to extend the boundaries of knowledge, and bring to light new truths, new evidence, and new relations.

In this order of mind we recognise the scientific investigator—the man of theory and formulæ, and we assign him the full share of merit to which his labours are entitled. We recognise him indeed as the first in the rank of benefactors; but in order that his investigations may be productive of their full benefit to society, his deductions must be brought under the view of another and different order of intelligence, and be examined in their bearings upon the practical pursuits of life. In this second order of mind we perceive the man of practical science—he who gives application and tangible value to the theoretical formulæ of the abstract philosopher. It is to the conjoined labours—the research and perseverance of these coadjutors in the field of physical truth, that we owe our advancement in the scale of physical wellbeing; and it is to their continued and mutual exertions that we are to look for further and higher progress in the arts of industry.

It would afford much instructive illustration of the history of civilization, to trace the path of discovery in the useful arts, from the half-articulated idea in which they were first shadowed forth in the deductions of pure science, to their full development. Thus, restricting our attention to practical mechanics, we recognise a science founded pre-eminently on calculation, and the relations of quantity—a scientific art based on the deductions of pure reasoning, grounding its exertion upon a moderate number of elementary propositions in theoretical mechanics and geometry. By means of these, to employ the language of one of the greatest of our living luminaries, we are enabled to diffuse over the whole earth the productions of any part of it; to fill every corner of it with miracles of art and labour in exchange for its peculiar commodities; and to concentrate around us, in our dwellings, apparel and utensils, the skill and workmanship not of a few expert individuals, but of all who in the present and past generations have contributed their improvements to the progress of our manufactures.

As mechanics have their origin in calculation, so chemistry, and the arts to which it is directly subservient, are deductions from those truths brought to light by experimental inquiry, into the properties of matter, and the material agencies around us. To the laboratory we are thus indebted for numerous of those necessaries, conveniences, and refinements which are in constant request. On this head we might dwell long, and find ample matter both for reflection and wonder. But when we turn to the conquests which practical science has effected for us, by a combination of the chemical and mechanical agencies, we almost cease to be capable of admiring the ingenuity and research which we find imbodied

in either separate department. Let us look only at the triumphs which have been effected by steam—by the vapour of boiling water. But a few years ago, we sought the great mechanical powers over the country in hilly regions, among waterfalls, or trusted to atmospheric influence, the most inconstant of natural agencies; we now have a power adequate to every variety of effect, which can be commanded in the midst of our most populous towns, and which may be extended in magnitude, and varied in application, according to the will of the mechanician. Again, contemplate its energies as an agent of locomotion by sea and land! By means of this power we have surmounted the uncertainty of the elements, and pursue our course with confidence against both wind and waves. On land we have, if possible, been still more successful. Here, by virtue of a few bushels of coals and the art of the engineer, we may be said to have annihilated distance, and given to time a ten-fold value. A time will come, says M. Arago, in his *éloge* of James Watt—"a time will come when the science of destruction shall bend before the arts of peace; when the genius which multiplies our powers—which creates new products—which diffuses comfort and happiness among the great mass of people—shall occupy, in the general estimation of mankind, that rank which reason and common sense now assign it. Then will James Watt appear before the grand jury of the inhabitants of the old and new worlds. Every one will behold him, with the help of his steam-engine, penetrating in a few weeks into the bowels of the earth, to depths which, before his time, could not have been reached without an age of the most toilsome labour; excavating mines; clearing them in a few minutes of the immense volume of water which daily inundates them; and extracting from a virgin soil the inexhaustible mineral treasures which nature has deposited there. Watt, combining delicacy with power, will twist, with equal success, the huge ropes of the gigantic cable by which the man-of-war rides at anchor in the midst of the raging ocean, and the microscopic filaments of the aërial gauze and lace. A few strokes of the same engine will reduce vast swamps to a fit state for cultivation; and fertile countries will also thus be spared the periodical returns of deadly pestilential fevers, caused in those places by the heat of the summer sun. . . . Installed in ships, the steam-engine will enable the mariner to play with calms and contrary winds, and to vanquish the storm of the elements; while on land it will draw in its train its thousands of travellers with a speed unequalled by the swiftest race horse."

But great and glorious as was Watt's merit in completing the invention of the steam-engine, it consisted simply in working out, and reducing to practice, physical truths long before discovered. His was a practical mind, capable of scanning the bearings of a principle, and of adapting to purposes of utility the formulæ and abstractions of the theoretical philosopher. There intervenes a great—an almost immeasurable distance between the experimental proof of the power of steam, as exemplified in the bursting of a hollow iron shell, and its application as a moving force in a Bolton and Watt engine; but when the shell exploded, a great physical truth was made known to the world—an element of power was discovered, which only required to be brought by mechanical ingenuity, operating upon previously known principles in the science of mechanics, under the control and dominion of man. This function, after many attempts with partial success, devolved upon Watt; he performed it to perfection, and in this consists the glory which hallows his name.

Early experiments upon the elasticity and tenacity of vegetable and animal filaments enabled mankind, ere the dawn of tradition, to replace their sheep-skin vestments with fabrics of linen, wool, and silk. In this were involved the arts of spinning and weaving, which Arkwright and Cartwright have extended, and reduced to organized systems of industry, no less remarkable for their magnitude than for their perfection.

At the present time, science and its applications seem to go onward almost together. No sooner is a new fact announced than it is made available for some useful purpose; and never was there an age so fertile in discovery as that in which we live. They may be thought to be of a minor kind; and we cannot perhaps hope that any discovery yet remains to be made of such a character of importance, and vital interest, as to work out a revolution in our industrial relations, equivalent to that effected by the steam-engine. We must expect rather to go on eking out and completing the fabric of our knowledge by the acquisition of absent details, and by arranging and harmonizing its parts, strengthening evidence and cancelling error, thus rendering the elements more and more intelligible, serviceable, and of readier access to the practical man. But while we do not anticipate any revolutionizing discovery in science or industry, we may still expect that many useful inventions are yet to be made, and improvements to be effected both in the chemical and mechanical arts and manufactures. These may not be great and brilliant, dazzling the world by their splendour; but they may confer upon us new facilities, and it may be, new advantages, of much influence on our social condition. We do not look to physical science as the sole instrument by which that condition is to be elevated to its proper standard; but, operating in conjunction with the moral aspirations which replace in our artisan population the besotted contentment of the serf, we may, without risk of disappointment, anticipate that amelioration awaits us; and that our mechanical ingenuity, instead of being a source of evil and of misery, shall become the blessing of the world, and the safeguard of our physical wellbeing.

GEOLOGY.

CHAPTER XVI.

THE OOLITIC SYSTEM.

In treating of the New Red Sandstone, or Saliferous System, we mentioned that it was the great depositary of rock salt in England; but the limits to which we feel ourselves sometimes prescribed, prevented further notice of these interesting deposits. There can be very little question that rock salt has been derived from the waters of the ocean; and, as such accumulation of salt is not confined to any particular formation (though occurring almost exclusively in new red sandstone in England), that the causes which produced them have been frequently repeated. What these causes were, it must be confessed, has not been altogether satisfactorily shown; but as the following attempt of Professor Phillips to account for that of Cheshire is ingenious, if not probable, we have no hesitation in presenting it:—

"The Cheshire deposits of salt lie along the line of the valley of the river Weaver, in small patches about Northwich. There are two beds of rock salt, lying beneath forty yards of coloured marls, in which no traces of animal or vegetable fossils occur. The upper bed of salt is 25 yards thick; it is separated from the lower one by 10½ yards of coloured marls, similar to the general cover; and the lower bed of salt is above 35 yards thick, but has nowhere been perforated. Whether any other beds lie below these two, is at present unknown. They lie horizontally, or nearly so; and both beds of salt are below the level of the sea. They extend into an irregularly formed oval area, in length one mile and a-half, in breadth about 1300 yards, ranging from N.E. to S.W. Gypsum, so abundant in many other salt mines, is found in most of the other clays associated with the Cheshire salt.

"The physical features of the country about Northwich are not very particular; yet sufficiently favourable to Dr Holland's hypothesis, that it was derived from the neighbouring sea. The valley of the Weaver is separated from that of the Dee by the sandstone ranges of Delamere forest, and the Peckforton hills; and from the course of the Mersey by an extension of the elevated ridge called Alderley Edge. Below,

these bordering hills come very close together, and naturally suggest the idea, that, in ancient times, there might, at this place, have been accidental bars formed, which, while they lasted, would exclude the inroads of the sea. If, by such an event, the sea lake flowing up the valley of the Weaver was converted into an inland sea, and if the supply of fresh water streams from the neighbouring country was very scanty, the natural progress of evaporation would certainly tend to dissipate the waters, to concentrate the solution of salt, and finally to cause in it a partial precipitation. At first, gypsum, or any other of the less soluble salts, would be formed, and perhaps mixed with the earthy sediments mechanically deposited in the lake; and afterwards, the salt be accumulated in the deepest parts of the water, in quantity proportioned to the evaporation of the liquid. If, at a subsequent time, the sea should burst the barrier, and inundate the valley, a new deposit of gypseous marls, and a bed of salt, would naturally be occasioned."

The oolitic rocks of England extend from Redcur, near Tees Mouth, to Filey Bay, on the east coast—a distance of nearly 50 miles. They reach westward to Stokesley, Northallerton, Thirsk, and Easingwold. The deposits of this formation in Yorkshire are connected with those of Lincoln by a narrow band of lias. From thence they extend through the counties of Rutland, Northampton, Huntingdon, Oxford, Gloucester, and portions of Somersetshire and Dorsetshire, on the coast of which they stretch from Lyme Regis to Weymouth and the Isle of Portland. Their breadth from east to West, in the Midland Counties, is from 40 to 60 miles. The formation is slightly developed, in Scotland, at Brora, in Sutherlandshire, and in Skye and some others of the Western Islands; at Ballycastle, in Ireland; and in Wales, at Aberthaw, Glamorganshire.

The rocks of the system are also extensively developed on the continent of Europe, particularly in France and Germany, where they ramify into mountain chains, extending into Italy, and even into Illyria, Dalmatia, Albania, and Greece. They occur on the south of the Alps, and form almost the entire mass of the Swiss and the German Jura range; in which, however, with the exception of the lower deposits of the lias, they vary considerably from the formations of England and Normandy in mineralogical character. The formations also occur in Spain, the Balearic Isles, and in the Appennines and the Atlas. The general appearance of the English oolitic districts is that of gently sloping valleys, overlooked with rocky escarpments, to the height of 1100 feet or more, lending a variety and interest to the scenery not possessed by the more level tracts occupied by the new red sandstone; yet withal tame to those whose early associations are connected with the picturesque beauties of the older rocks.

> "England, thy beauties are tame and domestic
> To one who has roamed on the mountains afar.

On the continent, however, where the limestones are more indurated, the rocks, as in the Juras of Switzerland, are peculiar, rugged, and precipitous.

The oolitic system is divided into three formations, distinguished from each other by their mineralogical and organic contents. These are, the Lias formation, consisting chiefly of argillaceous; the Oolitic, of calcareous; and the Wealden, of arenaceous deposits.

Lias.—The term Lias is a provincial word, signifying layers, applied to the lowest series of the system, from its limestones being in general of a flaggy structure. The beds composing the formation may be described in general terms. A series of blue coloured clays, containing much iron pyrites, layers of clay, ironstone, bitumen, and septarian (1) masses. These clays also contain beds of sandstone, sandy limestone, and strata of blue and white laminated or flaggy, or, as it is termed, lias limestones. It is subdivided into the upper lias shale, marlstone, and the lower lias shale, in Yorkshire; and near Bath, into the upper lias clay, blue and white lias limestone, and the lower lias marls. The lias is the best characterized of the secondary formations, with the exception of the chalk, in England, both as to its mineral features and its organic remains. When the limestones and clays are fully developed, the formation attains a thickness of several hundreds of feet. Professor Phillips, in the article "Geology," in the Penny Cyclopædia, estimates it at 350 yards, and divides it thus:—

Upper lias shale; full of characteristic Saurians, with ammonites, belemnites, and other shells.

Marlstone; replete with terebratulæ, pictens (clam shells), &c.

Middle lias shale; containing ammonites, gryphea (a species of oyster), and other shells.

Lias limestone; with ammonites, gryphea incurva, and other shells.

Lower lias shale, and coloured marls.

Oolite.—The name (from ὠὸν, an egg, and λίθος, a stone) of this formation is derived, like that of the lias, from the character of its limestones, many of which consist of round concretions, not unlike the grains which constitute the roe of fishes; on which account, oolitic limestone is frequently termed *roestone.* The oolitic structure is by no means confined to this formation, nor are all its limestones of that nature. As a whole, the formation may be regarded as an accumulation of sands, sandstones, marls, clays, and limestones; the average thickness of which may be estimated at from 1200 to 1300 feet. The subdivisions are, the upper, and the middle, and the lower oolite. The nature of each of these may be thus briefly described:—

The upper oolite, containing, 1st, the Portland beds, consisting of oolitic limestones; abounding in ammonites, trigonia, and other marine shells; green and ferruginous sands, with layers of chert (a species of quartz, allied to flint). 2d, The Kimmeridge clay, consisting of blue clay, with septaria, and bands of sandy concretions, with marine shells.

Middle oolite; containing, 1st, the coral oolite, or coral-rag—a limestone chiefly composed of corals and shells, with echini (sea urchins). 2d. Oxford clay, with septaria, and many shells, &c.; beds of calcareous grit, called Kelloway rock; also abounding in organic remains.

Lower oolite of Gloucestershire, Oxfordshire, and Northamptonshire; comprising, 1st. A coarse shelly limestone, called, in consequence of its utility as an agricultural manure, cornbrash. 2d. The Forest marble; beds of coarse shelly limestone, with an oolitic structure; sand, grit, and blue clay. 3d. The great oolite; thick, calcareous, oolitic limestones; containing the remains of extinct reptiles, corals, and shells; the last occurring most abundantly in the upper beds. The Stonesfield slate belongs to this division, remarkable for the only remains of a mammiferous animal yet discovered in secondary strata. It also contains the remains of reptiles, insects, and land plants. 4th. Fuller's earth beds; marls and clays; containing Fuller's earth, sandy limestones, and shelly layers. 5th. Inferior oolite; coarse limestone, with masses of conglomerated terebratutæ, and other marine shells; ferruginous sand, and concretionary blocks of sandy limestone and shells.

In Yorkshire, the lower oolite consists of, 1st, the Cornbrash. 2d. Sandstones and clays, with land plants and *thin layers of coal and shale;* calcareous sandstone, and shelly limestone. 3d. Sandstones, often carbonaceous, with clays full of plants; coal beds and ironstone. 4th. Limestone, and ferruginous and concretionary sands.

The oolite of Scotland, as it occurs at Brora, in Sutherlandshire, bears a striking resemblance to the lower oolite, as developed in Yorkshire; consisting, 1st, of alternations of sandstones, shales, and ironstones, with plants. 2d. Ferruginous limestone, with carbonized wood, and shales common to the oolite of England. 3d. Sandstone and shale, with two beds of coal.

Wealden Formation.—The fossils of this formation, which derives its name from the Wealds of Sussex and Kent, show it to have been of fresh water deposition, the shells being of fresh water genera. It is subdivided into, 1st, the Weald formation; a tenacious blue clay, containing subor-

dinate beds of sandstone and shelly limestone, with layers of septaria of clay ironstone. 2d. The Hastings Sands; gray, white, yellow, and reddish sands; and friable calcareous sandstones. 3d. The Purbeck beds; consisting of gray limestone, alternating with blue clay and sandstone shales.

The entire thickness of the Wealden strata, according to Dr Fitton, is about 800 feet; but he observes that no real measurement of the thickness of the strata has as yet been made. He observes, however, that, in the upper division, the Weald clay does not appear to be more than 140 feet. The total thickness of the Hastings Sands he estimates at between 400 and 500 feet. De la Beche's estimate of the Purbeck beds is 250 feet.

Organic Remains.—The fossils of the lias and oolite are generally distinct from those of the Wealden, inasmuch as, like the upper coal strata of the valley of the Clyde, it contains no zoophytes or shells indicating marine existence. The shells are either estuary or fresh water genera; yet the remains of the fish lizard (the plesiosaurus) is common to it, and the lias and oolite. It contains also both fresh and salt water tortoises; but those possessing by far the greatest interest are the Iguanodon and the Hylæosaurus discovered by Dr Mantell, and hereafter to be described.

The fossils of the lias and the oolite are very numerous and diversified, embracing all the great natural divisions of the animal kingdom. These include no less than 187 species of corallines, confined chiefly to the oolite; as are also 97 species of radiata, comprising the stelleridians, or sea-stars; the crinoideans or lily-formed animals; and echini, or sea-urchins. The Bivalve mollusca, including 61 species of Brachiopoda, amount to 384 species; the gasteropods, or snail shells, to 114 species; and the cephalopods (ammonites, nautili, &c.), 273 species; annelides, including the serpula and other worms which are furnished with calcareous tubes, 55 species. Of crustaceans (mostly of the lobster tribe), 22 species; insects, 20 species; fishes, 40 species; reptiles, 40 species; mammalia, 2 or 3 species. The plants are—marine, 4 species; cryptogamia, 39 species; endogens, 33; exogens, 4.

The endogens, or monocotyledons, are chiefly plants belonging to the cycas family, a class of plants intermediate between the ferns and palms The leaves and fruits of the fossils show considerable analogy to the forms of this tribe now existing in Southern Africa, India, and Australia. The corals, according to Phillips, present some general resemblance, with constant and obvious differences. The sponges are seldom so large as those in the South Seas, and appear most to resemble those of New Holland. The radiata are, according to the same authority, more like the crinoideans, the star-fishes, and urchins of the present seas, than those found in older strata. The beautiful genus, the Cidaris, in particular, exhibits a decided analogy to existing tropical species. The Brachiopoda, and the Mesomyona, those bivalves which have only one muscular impression on the valves, predominate over the Plagimyona, or those which have two muscular impressions; and the Cephalopods (2) over any other group of mollusca; "thus offering a broad distinction between the system of oolitic and modern life in the sea. The fishes belong mostly to the ganoid (splendid scaled) division of Agassiz, and are remarkable for the beauty of their preservation in the lias of Dorsetshire, Leicestershire, and Yorkshire. Among the Saurians, those which frequented the water predominate in number; but the largest forms were terrestrial (iguanodon and megalosaurus). The natural order of turtles was exceedingly developed in this period. Hugi has found in the Jura formation, about Soleure alone, more than twenty species of Emys (fresh water turtles). We are not to imagine the few mammalia, insects, and plants yet published from these formations a fair specimen of these races as they existed in the land during the oolitic period. Doubtless, we may believe that the insects of Stonesfield were not the only beetles that fed the Pterodactyle and Didelphides. Of these latter, the few jaws yet found convey only partial information; but it is interesting to know that the earliest mammalia of which we have any trace were of the marsupial (pouched) division, now almost characteristic of Australia, the country where yet remain the trigonia, cerithium, isocardia, (3) the zamia, fern tree, and other ferns so analogous to those of the oolitic periods."

Cidaris intermedia, from the middle oolite formations.

Constituted as the mind of man is, it appears not a little marvellous to look back on a condition of the earth swarming with living creatures of the most diversified forms, and many of them totally unlike anything that now exists on the land or in the waters, in periods vastly anterior to the time it pleased the Almighty to give existence to the human race. We are apt to appropriate all we survey as ours, and to deem all made for our particular use. But where was the boasted right of the lordly dominion of man, when the huge iguanodon trailed its more than enormous carcass through the cycadean forests of the secondary epoch—and where the lordly armadas that now ride on every sea when the ichthyosaurus and the plesiosaurus were the tenants and the tyrants of the deep? Ages had to roll on; thousands, perhaps millions of years had to pass away—new forms had to arise and become extinct—and the surface of the earth to undergo many a change ere man appeared qualified to understand the proud destiny allotted him, and to control not only the animals, but the elements to his will. Can all the arrangements of preadamite vitality, and all the combinations of inorganic matter, have been directed with reference to his moral or physical necessities? or does the Being who placed him here find equal delight in the bustle of irrational existence, as in the turmoils of the child of reason? Vain man! Is it not enough to know that we belong to a system of which the origin and the end are alike unknown; but that in understanding what is or what has been, we alone are capable of raising our thoughts to the great Artificer, and of placing confidence in the wisdom of his designs and the omnipotence of his power.

In the structure of living and extinct forms, we perceive the most exquisite adaptations to the modes of life to be pursued, and the means by which their wants can be supplied. Is this no source of instruction? Is there no happiness to be gained by such a contemplation? Does it afford no check to our presumption? Does it not minister to our humility? If it does, let us never look on the time spent in the study of nature as unprofitable, but as tending to implant in our minds sentiments of veneration and reliance towards that Power in whom all sentient and locomotive existences breathe and have their being.

The periods of secondary deposition were those in which the Saurian tribe seem to have attained the most extraordinary development, and many of them were formed after types which have no analogy among existing forms; such are the flying Saurians, the Pterodactyles, the Ichthyosaurians, and the Plesiosaurians. The hugest of all, the Iguanodon, has its representative in the recent Iguana; the megalosaurus combined the structure of the living crocodile and moniter, while the Steneosaurus and the Teleosaurus, approached in the structure of their heads and dental system, to the long-snouted Gavial, the crocodile of the Ganges, and the Hylæosaurus combined in its osteology the structure of the crocodile with that of lizards armed with dorsal spinal ridges. These, and all others yet discovered in rocks ranging from the older deposits of the new red sandstone to the terminating of the chalk formation, are all essentially distinct from species now in existence, and form in our museums most tangible evidences of the very different conditions of these parts of the earth at the time when they crawled upon the land, or swam in the water, or winged their flight through the air. A brief notice of these tenants of the ancient world is all our limits will afford.

Ichthyosaurus (*ichthys*, a fish, and *sauros*, a lizard.) Ten

species of this genus have been found in the oolite and lias formations, varying considerably in size, the largest measuring about thirty feet in length. In its general outline says Dr Buckland, the ichthyosaurus must have most nearly resembled the modern porpoise and grampus. The animal was furnished with four paddles, the front ones attached to a sternal arch of great strength, and in a manner admirably adapted to the habits of a creature requiring rapid motion through the ocean. A similar construction of the sternum (breastbone) is only met with among existing animals in that of the ornithorhynchus, or duck-billed water mole of New South Wales. The snout resembled that of the porpoise; the teeth were numerous, sharp and conical like those of a crocodile; the construction of the head was that of a lizard, with enormously large eyes; the vertebræ were doubly concave, like those of fishes, thus combining in its osteology the conformation of the whale, the ornithorhynchus, the crocodile, and a fish.

Ichthyosaurus communis.

Dr Buckland, in his Bridgewater treatise, mentions that the skeleton of one of these animals from Lyme Regis in Dorsetshire, preserved in the Oxford Museum, contains within the ribs a large mass of undigested fish scales, which it had devoured previous to its death, and as this mass of coprolitic matter occurs through the entire region of the ribs, he concludes that like existing crocodiles, it must have had a capacious stomach, whole human bodies having been sometimes found in the latter. The coprolites (dung-stones) voided by Ichthyosauri, containing the bones, scales, and teeth, of the animals they fed on, are found in great abundance in the lias formation. On the shore at Lyme Regis, these coprolites are so abundant, that they lie in some parts of the lias like potatoes scattered on the ground; still more common are they in the estuary of the Severn, where they are similarly disposed in strata of many miles in extent, and mixed up so abundantly with teeth and rolled fragments of the bones of reptiles and fishes, as to show that this region, having been the bottom of an ancient sea, was for a long period the receptacle of the bones and fæcal remains of its inhabitants. Thus when we see the body of an Ichthyosaurus still containing the food it had eaten just before its death, and its ribs still surrounding the remains of fishes that were swallowed ten thousand or more than ten times ten thousand years ago, all these intervals seem annihilated, time altogether disappears, and we are brought into as immediate contact with events of immeasurably distant periods as with the affairs of yesterday.

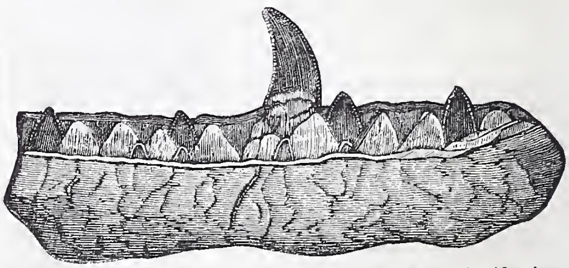
Plesiosaurus, (from *πλήσιον, near*, and *σαῦρος, a lizard*), This Enaliosaurian or fish lizard, resembled the Ichthyosaurus in its being furnished with four paddles, in the concave structure of its vertebræ, and in possessing the head of a lizard, and the teeth of a crocodile; but its neck was enormously long, while its trunk and tail possessed the proportions of an ordinary quadruped. The head was comparatively small, the teeth conical, very slender, and curved inwards. Professor Owen enumerates not less than sixteen species, some of which are upwards of twenty feet in length. It is conjectured that they lived in shallow seas and estuaries, as their remains occur both in the marine deposits of the lias and oolite, and in the fresh water or estuary formation of the Weald; the form of the neck appears to justify the supposition that they swam near the surface, with the neck projecting from the water, and bent like that of a swan.

In treating of this, perhaps the most hetroclitic of all animals, living or extinct, Conybeare observes:—"That it was aquatic is evident, from the form of its paddles—that it was marine, is almost equally so, from the remains with which it is universally associated—that it may have occasionally visited the shore, the resemblance of its extremities to those of the turtle may lead us to conjecture; its motion, however,

Plesiosaurus.

must have been very awkward on land; its long neck must have impeded its progress through the water, presenting a striking contrast to the organization which so admirably fits the Ichthyosaurus to cut through the waves. May it not, therefore, be concluded, (since, in addition to these circumstances, its respiration must have required frequent access of air,) that it swam upon, or near the surface, arching its long neck like the swan, and occasionally darting it down at the fish which happened to float within its reach. It may, perhaps, have lurked in shoal water along the coast, concealed among the sea-weed, and, raising its nostrils to the surface from a considerable depth, have found a secure retreat from the assaults of dangerous enemies, while the length and flexibility of its neck may have compensated for the want of strength in its jaws, and its incapacity for swift motion through the water, by the suddenness and agility of the attack which they enabled it to make on every animal fitted for its prey which came within its reach." For a full account of these remarkable animals we have pleasure in referring the reader to the articles under their respective names in the *Penny Cyclopedia*, and to the Bridgewater Treatise of the Rev. Dr Buckland, to whose enthusiastic disposition and graphic pen we owe so much of the history of the inhabitants of the ancient earth.

Megalosaurus, (from *μέγας*, great, and *σαῦρος*, a lizard) Remains of this crocodelian have been found in the Oolite at Stonesfield, in Oxfordshire, and at Besançon, and also by Dr Mantell, in the Wealden of Talgate forest. From the size and nature of the bones found, Cuvier considered the animal as partaking of the structure of the moniter and crocodile, and to have been from forty to fifty feet in length. The femur and tibia measure nearly three feet each, so that the hind leg must have been about six feet long. The thigh and leg bones of crocodiles, and other aquatic quadrupeds, are solid throughout, but those of the Megalosaurus were hollow like those of land quadrupeds,—an arrangement by which both lightness and strength are secured. It is therefore conjectured, that the Saurian, under consideration, lived chiefly on land. The structure of its serrated teeth indicate it to have been carnivorous.



Anterior extremity of the right lower jaw of Megalosaurus in side view, one-fourth of natural size.

Pterodactyle.—(*πτερὸν, a wing*, and *δάκτυλος, a finger*).—Amongst all the anomalous forms with which zoological research has rendered us acquainted, no one is certainly more singular in its conformation than the Pterodactyle genus. In their external appearance they had much resemblance to a large vampire or bat with a short tail, an extremely long neck, a large head with enormous eyes, enabling them to fly

by night; their beaks were long, and armed with sixty sharp conical teeth, but their most remarkable character consisted in the excessive prolongation of the second toe of the fore foot, which was fully twice that of the trunk, and is supposed

Pterodactylus crassirostris—restored by Goldfuss.

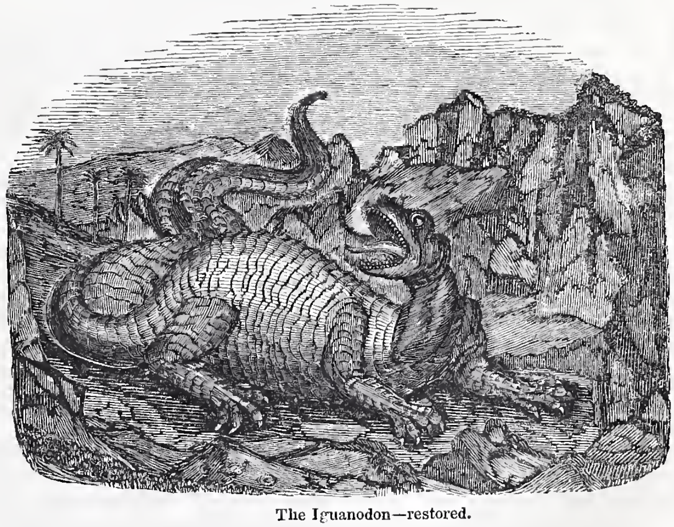
to have supported some membrane which enabled the animal to fly. The fingers terminated in long hooks, like the curved claws of the bat; the form and size of the foot, leg, and thigh, show that it was capable of standing either firmly on the ground, or of perching on the branches of trees. Dr. Buckland also conjectures that it had the powers of swimming. Thus like Milton's "all qualified for all services and all elements," the creature was a fit companion for the kindred reptiles that swarmed in the seas or crawled upon the shores of a turbulent planet.

"The fiend,
O'er bog or steep, through strait, rough, dense, or rare,
With head, hands, wings, or feet, pursues his way,
And swims, or sinks, or creeps, or flies."

"With flocks of such like creatures flying in the air, and shoals of no less monstrous Ichthyosauri and Plesiosauri swarming in the ocean, and gigantic crocodiles and tortoises crawling on the shores of the primeval lakes and rivers; air, sea, and land must have been strangely peopled in those early periods of our infant world."

Hylæosaurus (Weald Lizard). The lizard thus denominated by the discoverer, Dr. Mantell, was about twenty-five feet in length, and is chiefly remarkable by a large spiny process along the back, which must have given to such a creature a terrific appearance. Such process is found in many of the living lizards.

Iguanodon.—The remains of this, the most gigantic of all reptiles living or extinct, were also made known to the world by Dr. Mantell. The bones obtained by the Doctor indicate the existence of an herbivorous lizard, allied in structure to the iguana of the West Indies; seventy feet in length, and four and a half feet in circumference round the body. A thigh bone measures three feet eight inches, and thirty-five inches in circumference, and the bones of the foot show it



The Iguanodon—restored.

to have been six and a half feet in length. The nose of the animal was armed with a horn, equal in size, and resembling in form the lesser horn upon the nose of the rhinoceros,—an apparatus which also exists on the nose of the iguana. The teeth, some of which are two and a half inches in length, are deeply serrated, and their resemblanee to those of the iguana, clearly demonstrate that, like it, it was of herbivorous habits. Besides the remains found in Talgate forest, in strata of the Wealden formation, Dr Mantell mentions the discovery of another at Maidstone, in an arenaeeous or sandy limestone, called Kentish rag, belonging to the Shanklin sands. This rock, he observes, abounds in the marine shells, which are characteristic of that division of the chalk formation. In the quarry in which the remains of this Iguanodon were found, Mr Benson has discovered fossil wood by the boring shells, the lithodomi; impressions of leaves, stems of trees, ammonites, nautili, &c.; large conical striated teeth, which are referrible to those extinct fossil fishes which M. Agassiz denominates sauroid, or lizard-like; scales and teeth of several kinds of fishes, and among these a jaw or mandible of that singular genus of fish, the Chimera.

The geological position of this specimen forms an exception to what has been previously remarked of the fossils of the Wealden; for, while the bones in the latter were associated with terrestrial and fluviatile remains only, the Maidstone specimen is imbedded in a marine deposit. This discrepancy nowise affeets the arguments as to the fluviatile origin of the Wealden; it merely shows that part of the delta had subsided, and was covered by the chalk ocean, whilst the country of the iguanodon was still in existence. The body of the iguanodon was then drifted out to sea, and beeame imbedded in the sand of the ocean; in the like manner, as at the present day, bones of land quadrupeds may not only be ingulphed in deltas, but also in the deposits of the adjacent sea. This specimen, continues the Doctor, clearly proves that the separate bones found in the strata of Talgate forest, and which I had assigned solely from analogy to the lizard tribe, have been correctly appropriated, and we obtain many interesting facts relating to the structure and economy of the original. I can but notice one of these inductions. As the iguana lives entirely on vegetables, it is furnished with long slender feet by which it is enabled to climb trees with facility in search of food. But no tree could have borne the weight of the colossal Iguanodon; its movements must have been confined to the land and water, and it is evident that its enormous bulk must have required limbs of great strength. Accordingly, we find that the hind feet of the hippopotamus, rhinoceros, and other large mammalia, are composed of strong short massy bones, furnished with claws, not hooked as in the iguana, but compressed as in the land tortoises, thus forming a powerful support for the enormous leg and thigh. But the bones of the hands or fore-feet, are analogous to those of the iguana—long, slender, flexible, and armed with curved claws, the exact counterpart of the nail-bones of the recent animal, thus furnishing prehensile instruments fitted to seize the palms, arborescent ferns, and dragon-blood plants, which probably constituted the food of the original. Thus we have another interesting example of that admirable adaptation of structure to the necessities and conditions of every form of existenee which is alike manifest, whether our investigations be directed to the beings around us, or to those which have long sinee passed away.

We must defer entering upon a description of the other organic forms, peculiar to the secondary formations, till our next.

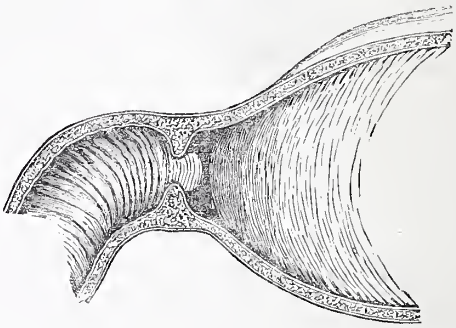
*** (1) Septarian: concretionary masses of limestone or ironstone, with intersecting veins of spar or iron pyrites. (2) Cephalopods: mollusca, which have their organs of progression and prehension arranged round the head like the nautilus and cuttle-fish. (3) Trigonia, a triangular formed bivalve; cerithium, a species of screw shell with a notched aperture; isocardia, a heart-shaped shell resembling the cockle (cardium).

ANATOMY AND PHYSIOLOGY.

CHAPTER XVIII.

OF DIGESTION.

The *stomach* is a bag of a conical shape, the large end of which lies in the left side of the belly immediately beneath the diaphragm, and the small end at the hollow which is familiarly known as the pit of the stomach. It is bent, besides, on account of its passing across the spine; the concave border being directed backwards, and the convex border forwards. When the stomach is nearly empty, the convex border hangs downwards, and when filled, it rises forwards, producing sometimes a painful feeling of distension. This is most felt by persons who are troubled with flatulence after taking food. In such persons, if one finger be laid over the stomach, and struck with one of the other hand, it will sound like a drum, in consequence of the quantity of air which is contained within it. There is always, however, a certain quantity of gas in the stomach and whole course of the intestinal canal. The gullet enters the greater or left end of the stomach, and the small intestine commenees at its smaller or right end. These two orifices are upon the same level, so that the food does not run out of the stomach, but can get out of it only by the contraction of its coats. These are muscular, as indeed are the coats of the whole intestinal canal, and are particularly strong at the smaller end, where they form a ring, which contracts, and completely closes the



communication between the stomach and intestines. The stomach is lined with a velvety mucous membrane, similar to, and continuous with, that which lines the mouth and gullet. This membrane is full of minute blood-vessels, from which the mucous fluid is poured, which serves at once to mingle with the food and assist its digestion, and to prevent the coats of the stomach from injury. Accordingly, when any irritating substance is swallowed, more mucus is immediately poured out, which envelopes it, and prevents as far as possible the evil consequenees which might ensue.

Besides the mucus, another fluid is poured into the stomach by its coats, which is called the *gastric juice*. This is a clear ropy fluid, of a saltish taste, possessing the power of dissolving all substances which are fit for food. It has no effect, however, on the living stomach; but we often find, on opening persons who have died suddenly, with a quantity of the gastric juice in the stomach, and no food, that the dead stomach itself has been dissolved, and that a large irregular opening exists in its back part.

After a meal, the stomach becomes agitated by a constant succession of gradual contractions, which turn the food gently from the left side to the right, and back again, churning it and mixing it all well together, so that it acquires the appearance of so much porridge or gruel, the different aliments that have been swallowed becoming so blended as to form a homogeneous mass of a grayish colour. It is turned back-

ward and forward for three hours or more, until the delicate sense, which resides in the orifice leading into the intestines, is satisfied that it is fit to pass farther; the constricted ring then opens to let it through, and it passes into the commencement of the bowels. But such is the delicacy of perception with which the outlet of the stomach is endowed, that it will not let undigested food pass, until it has been rolled about in the stomach for many hours, and presented to it and rejected many successive times. Indeed, it often refuses to allow such food to pass at all; and then there is no help for it but that it be ejected summarily by vomiting.

Let us now inquire into that part of the process of digestion which goes on within the stomach.

In this organ the first of these changes takes place which fits the extraneous matter swallowed as food, for being received into the circulation of the fluids of the living body, and for becoming a component part of the animal. For now the gastric juice, acting on the semifluid mass, gradually dissolves out the digestible part, and, entering into union with it, produces a new, thick, turbid fluid, which has been called *chyme*. The alimentary mass changes its sensible and chemical properties by an operation peculiarly animal, or depending on the existence of life. The change is not strictly chemical; for we do not find anything like it going on out of the living body. Animal or vegetable matters, in any vessel possessing the heat and moisture of the stomach, would quickly fall into fermentation and become sour, but the living properties of the stomach prevent this. No superfluous acid is formed in the stomach in the healthy state; but when it is weak, and its nervous action deranged, then the symptoms which announce the diminished power are the extrication of gas, and abundant formation of acid, with oppression and uneasy sensations. The stomach having been stimulated by fulness, both of food and wind, and still more by the peculiar excitement caused by the food undergoing digestion, its muscular coat is brought into action, and its contents delivered over into the commencement of the small intestine.

We are solicited to take food by the uneasy sensation of *hunger*,—a sense which appears placed as a safeguard, lest the body should be permitted to wear out. In the artificial state of society in which we live, where regular hours are appointed for meals, so that one shall succeed before the interval after the preceding shall have been so long as to produce pain, no one almost knows what hunger really is, except by some self-inflicted abstinence on a fishing or shooting excursion. Yet though unaccustomed to be felt by us, there is an unpleasant sensation produced by want of food, amounting at first only to a feeling of emptiness, lassitude, and indescribable uneasiness, but gradually getting worse until it end in actual pain, as if the inward parts were all on fire. There was a time when it was thought that the internal surfaces of the empty stomach rubbing against one another produced hunger; and hence arose the vulgar phrase of "taking the wrinkles out of your stomach," by satisfying the appetite; but that is too mechanical an explanation. If the sensation proceeded merely from such rubbing of the coats of the stomach, food swallowed would be more likely to aggravate than to assuage the gnawing of hunger; to excite the action of the stomach would be to excite the appetite; and an irritable stomach would be attended with an insatiable desire of food. But something more than mere emptiness is required to produce hunger. By some of the ancients, hunger was referred to the weight of the liver dragging down the empty stomach, forgetting that the liver is as heavy, and will drag as much, when the stomach is full as when it is empty. By others, with more probability, it is supposed to proceed from the action of the gastric fluid on the nerves in the coats of the stomach. Hunger is like thirst, a *sense* placed as a safeguard to call for what is necessary for the system, and depending on the general state of the body. Morbid craving may proceed from many causes; a tapeworm in the bowels has occasioned voracious appetite, and ardent spirits and high seasoning excite it even when the stomach is full; but natural hunger has always a reference to the wants of the general system.

Thirst is a sensation seated in the tongue, throat, gullet, and stomach. It depends on the state of the membrane which lines these parts, and of the fluids which naturally moisten it, and may arise either from a deficiency of that fluid, or from an acrid state of it. It would appear to be placed as a monitor calling for the dilution of the fluids by drink, when they have been exhausted by perspiration and the fatigue of the body, or when the contents of the stomach require to be made more fluid, the more easily to suffer the necessary changes of digestion. The feeling of thirst, when carried to an extreme, is said to be much harder to bear than that of hunger; and the most dreadful picture is given of it in some accounts of shipwrecks, particularly in that published of the horrible calamities endured by the crew of the French frigate, the Medusa, on the coast of Africa.

The changes which take place on the tongue, in consequence of the state of the stomach and intestines, depends on its intimate connexion with these organs, and the nervous sympathy which is established between them. The state of the tongue, the loose or viscid state of the throat, the secretion of the saliva, the softness or huskiness of the voice, are all influenced by the state of the stomach. We attend more to the effects on the tongue than to any of the rest, because it is more accessible, and affords us a sort of index to the state of the stomach. In health, it is clean, red, and moist; in indigestion, it is white; in disorders of the bowels it is more or less thickly furred; after excess in wine, it is dry and chopped; and in bad cases of fever, it becomes quite black.

A great deal of nonsense has been written, and a great many absurd experiments have been performed, with the view of elucidating the nature of digestion on the one hand, and the digestibility of various kinds of aliment on the other. A very curious case, however, occurred in America, by which immediate access was had to the living stomach, and the experiments which were performed have been published by their author, Dr. Beaumont of Plattsburgh, in the state of New York.

A young man, of good constitution, when eighteen years of age, was accidentally wounded in June, 1822, by a musket loaded with buck-shot fired close beside him. The shot tore away a piece of his left side, about a handbreadth in extent, making a hole in his stomach. For seventeen days everything that was taken by the mouth passed out at the hole; but after that period, by means of properly adapted bandages, the food was enabled to be retained. The wound gradually diminished, until it became of the size and nearly of the appearance of the natural anus, the lining membrane of the stomach joining the skin all round; and about a year and a half after the accident, the membrane came to form a sort of valve, which prevented anything from running out, although it readily permitted the finger, or a tube, or a tea-spoon, to be introduced. By two years after the accident, he had completely recovered his health and strength; and Dr Beaumont conceived the idea of making use of the extraordinary opportunity thus put in his hands, of examining into the nature of digestion.

When the stomach was empty and at rest, the interior of its cavity could be examined to the depth of five or six inches, and food and drink could be seen entering it through the ring at the entry of the gullet. The solvent power of the gastric juice was ascertained in the most conclusive manner. Almost every variety of aliment, whether animal or vegetable, when submitted to the action of the fluid taken from the stomach when fasting, and kept at the temperature of about 100°, was found to become in a few hours reduced to a paste, which resembled very nearly the contents of the stomach after the same kinds of aliment had been eaten. The rapidity with which substances were dissolved by the gastric fluid out of the body, was always in proportion to the purity of the fluid, and the tenderness and state of minute division of the substances submitted to its action. Milk and the white of egg

were invariably found to become first curdled by the fluid, and then dissolved.

The periods required for the solution of various substances in the gastric juice, out of the body, varied as follows:—Sago and tapioca, boiled, were completely dissolved in about three hours and a quarter; fresh bread, in about four hours and a half; milk, in about the same time as bread; calf's-foot jelly, in about four hours and three-quarters; soft-boiled eggs in six hours and a half; hard-boiled, in two hours longer; oysters, raw and entire, seven hours and a half; stewed, eight hours and a half; beef-steak, in eight hours; boiled beef, in nine hours and a half; boiled mutton and raw pork, in eight hours and a half; beef suet, boiled, in twelve hours; mutton suet, boiled, in ten hours; cream, in twenty-five hours and a half; olive oil, in sixty hours. In these experiments the gastric juice employed was about eight times the quantity of the substance to be dissolved. It will be seen from these experiments, that fat and oily food was among the articles which presented the greatest resistance to the solvent powers of the gastric fluid; and Dr Beaumont found this to be the case in the stomach as well as out of it. Some of his experiments indicate that the digestibility of this sort of food is facilitated by a slight admixture of bile with the gastric juice, and that very generally, when aliment containing fat is eaten, bile passes up into the cavity of the stomach.

The following are the conclusions which Dr Beaumont has deduced from his experiments on his patient:—

"The ordinary time required for the complete digestion of the food received into the stomach, in a healthy state of that organ, is generally three hours and a half. The facility of digestion is modified, however, by many circumstances, as the peculiar nature of individuals, their habits, the nature of the food, and the manner in which it is prepared: minuteness of division, and tenderness of fibre, would appear to be the two great essentials for the speedy and easy digestion of the aliment.

"Albumen (white of eggs,) if swallowed either raw, or very slightly coagulated, is, perhaps, as rapidly digested as any article of diet we possess. If perfectly hardened by heat, and swallowed in large solid pieces, it experiences a very protracted digestion. Fibrin (red muscular flesh,) and jelly are affected in the same way; if tender and finely divided, they are disposed of readily; if in large solid masses, digestion is proportionably retarded."

Animal fat is invariably and very quickly rendered fluid by the heat of the stomach, and, with any species of oily food, resists for a long time the action of the digestive organ and its fluids. It has already been noticed above, that this sort of food generally requires an admixture of bile (which is alkaline,) to render it soluble.

"Bulk is, perhaps, nearly as necessary to the articles of diet as the nutrient principle. They should be so managed that the one of these qualities should be in proportion to the other. Too highly nutritive diet is probably as fatal to the prolongation of life and health, as that which contains an insufficient quantity of nourishment."

A commencing state of putrefaction, sufficient to render the muscular fibre slightly tender, was found to increase the digestibility of most kinds of flesh. This is a practice which every housekeeper in this country adheres to, though without knowing the principle on which it is founded.

Vegetable aliment, generally speaking, he discovered to be slower and more difficult of digestion than animal. Its solution in the stomach is greatly influenced, however, by division and tenderness of fibre. Raw vegetables often pass through the stomach in an undigested state, while other food is retained and fully digested. Here is a hint for the eaters of salads.

The thorough mastication of the food is essential to healthy digestion. "If aliment," remarks the author, "in large masses be introduced into the stomach, though the gastric juice may act upon its surface, digestion will proceed so slowly, that putrefactive changes will be likely to commence in its substance before it will become completely dissolved. Besides, the stomach will not retain undigested masses for a long time, without suffering great disturbance." Consequently, eating too fast impedes digestion, by introducing food into the stomach in a state unprepared for the actions of that organ and of its fluids. Also, if food be swallowed too rapidly, more will in general be taken into the stomach before the sense of hunger is allayed, than can afterwards be digested with ease.

Overloading the stomach with food, is invariably found to interfere with the regular process of digestion; a portion remaining for a long while undigested. This may soon become rancid, or sour, running into the acetous fermentation; and if not rejected by vomiting, causes pain and irritation of the stomach, and other distressing symptoms; or if it be permitted to pass into the intestines, its presence almost invariably gives rise to colic, flatulence, or even more dangerous affections.

Condiments, as spices, though they may at first excite the action of a debilitated stomach, yet, when used habitually, never fail to produce debility of that organ, and in this manner impede digestion. Salt and vinegar are exceptions, and are not obnoxious to this charge when used in moderation. They both assist digestion—vinegar, by rendering muscular substance more tender—and both, by producing a fluid having some analogy to the gastric juice. Spirituous, and probably all artificial drinks, impede more or less the digestive process; some more so than others, but none can claim exemption from the general charge. Even tea and coffee, the common beverages of all classes of people, have a tendency to debilitate the digestive organs.

After a full meal, rest should be taken for at least an hour. After that, moderate exercise rather aids digestion, but severe and fatiguing exertion always impedes its performance. An experiment was made by a medical man on a couple of dogs, of the same litter, and in equal health. After giving them a good dinner of flesh, one was taken out and hunted for four hours, while the other was permitted to lie down and sleep. They were then both killed; the hunted dog had the meat in his stomach quite undigested; the idle one had it quite gone. The lesson is a most instructive one.

BOTANY.

CHAPTER IV.

THE STEM.

It was explained in Chapter III., that the root of a plant passes downward from what is called the crown, or neck, or life-knot, where the root and stem meet, and which seems to belong indifferently to either. We have now to observe that the *stem* or *trunk*, or *ascending axis*, arises from this knot, and invariably makes its way at first more or less upward, whatever may become its subsequent direction. It passes upward from the root, getting smaller as it ascends, and so putting on the form of a cone. It gives support to the leaves, flowers, and fruit, and transmits to them the nourishing juices absorbed from the earth. These juices, it is most probable, undergo some chemical change, while passing up through the vessels of the stem.

With regard to their structure and arrangement, stems are simple, (40), as those of the white lily among flowers, and the palms among trees; or branched, as in most trees and shrubs; they may be hollow, as in the grasses and *umbelliferæ*, but more generally they are solid.

With regard to their direction, the stems of most plants *rise from the ground*, (it has been already said that they all rise *from the root*,) bearing the branches and leaves, the flowers and fruit. Most of these are able to support their own weight, and are simply described as *ascending;* some creep along the ground, as the Ground Ivy; indeed the creeping root, (28, Chap. III.) is more properly a creeping stem; some seem to fall on the ground, and are *decumbent* or *procumbent;* others have the wish to rise, but cannot support

themselves without clinging to their neighbours, round which they twine, as do the Convolvulus and the Hop. It is curious

Fig. 40.

Fig. 41.

Fig. 42.

Fig. 43.

that these maintain invariably this course to the right (41,) or the left (42,) with or from the sun. Many plants have the stem running along the ground for a short way at first, and then rising, as in many of the Speedwells; (43,) these are said to be *decumbent at the base.* A variety of the stem is what is called a *runner*, with which we are familiar in the Strawberry (44). It is plainly not a proper stem, for it gives off no branches nor leaves; and it is not a root, for it does not go down into the earth, and we see the roots quite distinct in addition. Another variety is the *sucker*, (45,) which is a new stem given off by the root at some distance, as in the Poplar.

In many plants the stem is entirely wanting, the leaves springing from the ground directly, without stalks, and the flowers also; for what is commonly called the stem of a snowdrop, is not a botanical stem; having no leaves on it, and no branches, it is called a *scape*, (46), as in some of the garlics, and most of those plants which have bulbous roots. A stem is *simple* if it gives off or divides into no branches, having only the pedicels or flower stalks, and the leaves, attached to it; if on the contrary, it divides more or less frequently, it is said to be *compound.* When this division takes place regularly into successive pairs (47), it is said to be *dichotomous.*

Fig. 44.

Fig. 45.

Fig. 46.

Fig. 47.

The *Branches*, or subdivisions of the stem, are merely extensions of the trunk, for the support of the leaves and parts concerned in fructification. They consequently present the same structure as the stem, an account of which will be given a little further on. In general they come off irregularly; but sometimes in two opposite ranks, and sometimes in four. In trees, we observe four different ways in which they separate from the parent stem. They may be *patent or spreading* (48), as in by far the most of our trees; *horizontal or divergent* (49), as in many of the Pines; *appressed*, as in the

Fig. 48.

Fig. 49.

Lombardy Poplar, (50), or *pendulous or drooping*, as in the Pendulous Beech (51), or the Weeping Willow.

Fig. 50.

Fig. 51.

The distinctions between a *tree*, a *shrub*, and an *herb*, may be mentioned here. A tree is perennial, and rises from the ground by a single trunk; a shrub is also perennial, but breaks the ground in a number of adjacent trunks; and both agree in having hard woody stems. An herb again is soft and green, and its stem dies away after its fruit has been perfected; whether after one season, as the Lily; or after two, like the common Kale. The herb is therefore obviously distinct from the other two; for the tree and shrub do not depend for their difference on their size, although that quality generally accompanies the other difference, but upon the arrangement of the stem. The common Holly, for example, is a tree, although it is seldom seen of any considerable size; the Barberry is a well-known example of a shrub.

The most important function of the trunk, both in its ascending and descending parts, including its radicles and its smallest twigs, is to convey to the foliage, flowers, and fruit, the nourishment taken up from the soil; and to carry on this function, its structure is with great care and delicacy adapted. A circulation of fluids seems essential to all organized beings—and in all such, it can be detected going on by means of the microscope. If a thin portion of a leaf be examined, canals will be seen like those in figure 19, page 35 of this volume, through which globules of fluid are seen hurrying in certain directions. In the lowest orders of plants, as the Lichens and Mosses, there do not appear to be any vessels, but the whole structure seems composed of contiguous cells. The cells must communicate by small openings, so that their sides are permeable to fluids, for we find that, when a portion is put into water, the whole becomes by-and-by traversed by the fluid; just as we see in a sponge, when the end of it is laid in a basin, that even the part which is above water becomes filled. In the very young plant, when just shooting from the seed, the structure seems to be entirely cellular, as seen in the figures in page 34; but as it grows, these cells come to open into one another in a longitudinal series, so as to form a long and perfect tube or vessel, as shown in fig. 15, page 35 of this volume. The nature of the circulation of plants will be explained in a following article.

In the lowest orders then, the nourishing fluids are ab-

sorbed from the ground by means of *cells*, which form *pith* and structures like it, while in the higher orders, the *tubes* or *vessels* can actually be seen. In herbaceous plants, the cellular tissue is interspersed with fibres, as any one may see on breaking a stem of grass, or the blade of a cabbage; and these fibres, when examined with the microscope, are distinctly seen to be tubular. This is illustrated by the cross section of a stem (54), with vessels scattered through it. Between the green softness of herbs, and the woody texture of shrubs, we find a tribe intermediate, so far as mere structure is concerned, where there is a hard woody shell on the outside, next a spongy part containing fibres, which are vessels, and lastly a large mass of pith in the centre, as in the common bramble. Pith is at first soft and green, and is altogether cellular and without vessels, and is doubtless of use to the growth of the young plant, during its transition from being cellular to becoming vascular, before the vessels have been properly formed. All shrubs and trees are possessed of it, but in most of them it is exceedingly small at the very centre; and frequently in old stems it is found quite dried and shrivelled up—a proof that it is no longer serving any useful purpose. The gradual compression and lessening of the pith by the growth of the surrounding wood is well seen in the Bourtree or Elder. Every country boy knows that its long straight shoots are very light, with a thin shell, and three-fourths of their thickness consisting of pith; while the trunks of several years old have the proportions reversed, the wood being, perhaps, half-an-inch thick, while the pith is reduced to one-eighth, requiring merely the application of a hot wire to remove it altogether, and complete a most satisfactory tow-gun!

There is a particular kind of stem peculiar to the grasses, styled a *culm* (52). It presents a smooth hard outside, which still is hardly separate enough to be called a cuticle, within which it is cellular, and containing vessels, and at certain distances it presents knots, where the upper part of the stem ceases to be received into a sheathing leaf growing up from the lower. The stem of a Fern (53) is called the *stipes*, and is solid and almost entirely cellular, and the green part of it is called the *frond*, differing from a leaf in this obvious mark, besides others which exist in its minute texture, that it bears the fructification upon its under side.

Fig. 52.

Fig. 53.

In regard to their structure, plants then are either cellular or vascular; and vascular plants are of two kinds, as in this table.

1. Cellular.
2. Vascular. { endogenous. / exogenous.

Cellular plants, it will be understood, are those of the very simplest texture, consisting of a mass of cells, covered by a membrane which may be called their cuticle. Some of them present the appearance of fibres, but these are merely cells, compressed and elongated, as will be understood by looking at fig. 6, page 34, where the cells near the vessels are approaching this form. These plants, like animals which are very low in *their* organization, cling to life with great tenacity. Every one knows how a worm may be cut in pieces, and yet each piece will move away, and come to have a head and a tail grow to it, and continue to live. In like manner, any portion of most cellular plants, which has been cut off, will live by itself, and become independent. Nay, more, though dried and withered, if put into water, it will absorb it; its tissue will become distended, and it will soon be able to carry on all its functions as before. Of this kind are mushrooms, mosses, lichens, and seaweeds.

Vascular plants, possessing a distinct system of vessels or tubes, are of two kinds, arranged in two great divisions, named from two Greek words, *Endogenous*, signifying *growing inwards*, and *Exogenous, growing outwards*.

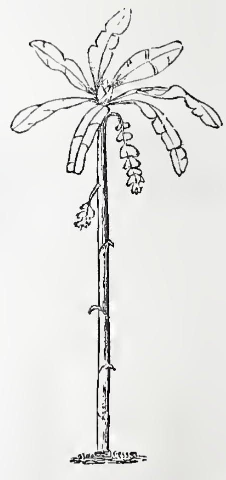
The Endogenous stems are exceedingly simple in their structure, as those of the Narcissus, the Iris, and the Lily of the Valley. When cut across, (fig. 54), they present a bundle of vessels, irregularly dispersed through cellular tissue, firm at the outside, and loose internally, and covered over with a cuticle which is often very thin. A beginner will recognise a mark of simplicity in their leaves; for the veins do not branch across from the mid-rib, but run nearly parallel on to the end. Of course, there is a certain growth outwards at first, till the stem acquires its proper thickness; but after that, it increases none laterally, but only in length. A stalk of corn, for instance, after it has got three feet high, remains of the same thickness as when it was six inches; which cannot be said of any tree or shrub whatsoever. Fig. 55, shows a longitudinal section of a stem, the first vessels rising to the outside, the newer ones within. The outer ones are closer to one another, while the stem is looser towards the centre. In this country, the endogenous plants are all small and herbaceous, with soft stems; but in warm climates a large number of the trees grow in this way. Of course, as has just been said of the corn-stalk, they must grow outwards at first, probably by the simple diffusion of the nourishing juices through the cells, until, as in the case of the bamboo, they reach perhaps a foot in diameter, having been at first not more than an inch; but when they have reached a certain point, they get no thicker, because the outer part has become condensed and hard, by the pressure from within, the new matter descending in the centre of the stem, and pushing out the old. Since then the oldest matter, and the most condensed, is on the outside, we would expect that the outside of the endogenous would be the hardest part, contrary to what we see in our trees here, where the old hard wood is nearest to the centre. And so it is; the prickly pole Palm has the hardness of whalebone on the outside, while in the centre it is quite soft.

Fig. 54.

Fig. 55.

No buds appear on the sides of these trees; because from the hardness of the bark and outer layers they could never grow. They are all collected into a common cone, which springs from the very top of the tree. The Banana, (fig. 56), is a good example of the endogenous trees of tropical climates. It is from twenty to thirty feet high, and nearly of equal diameter throughout. A cluster of leaves is seen on the top, the lower one of which is hanging down already withered, and will by and by drop off, as its predecessors have done, leaving their bases to remain and form the outer covering of the new part of the stem. In the middle of the cluster of leaves, is seen a *terminal bud*, to be next developed; it will rise up and become a new cluster, and be itself pushed away by its successor.

Fig. 56.



From what has been said, it will be plain that plants of this description never can attain great thickness, but may arrive at great height. Certain species of the palm, with whose forms we are familiar in pictures of tropical and eastern scenes, reach a height of a hundred or even two hundred feet, with a very moderate thickness at their bases.

It also results from their structure, that by and by the hard unyielding case which their external layers form, will become filled—completely crammed with the more recent growth, until at length the vascular tubes will be so com-

pressed, that the juices will no longer flow through them, and the tree will die for want of nourishment, by the same process by which a part of a living body mortifies and drops off, when a string is kept tightly round it so as to arrest the circulation. The age of these trees is consequently limited; two or three centuries is their utmost space, while exogenous trees have no such certain bounds set to their growth,—the oak and the yew especially living for six or seven hundred years. It should be remarked, besides, that from the absence of those concentric rings, which are seen when an exogenous tree is cut across, it is impossible to determine with accuracy their age; the only data to guess from being the number of scars left on the outside, from the annual decay of the bunch of leaves.

With respect to its *form*, the stem may be *round* or *cylindrical* when cut across; *semi-cylindrical*, when flat on one side and round on the other; *compressed*, when more or less flat on both sides; *two-edged*, when more or less compressed, with two opposite sharp edges; *three-edged* or *triangular; quadrilateral*, four-sided; *five-cornered;* when the number exceeds five, it is called *angular*, or *many-cornered*. It may be *winged*, when the edges or corners are extended into a thin leafy border; *jointed* or *articulated*, when formed of distinct parts united by portions of smaller size.

With respect to its *surface*, the stem may be *smooth*, destitute of all kinds of hairiness; *even*, destitute of all inequality; *polished*, or *shining*, smooth and reflecting the light; *viscid*, or *clammy*, covered with a glutinous juice; *scaly*, covered with scales; *warty*, with small hard protuberances; *papillous*, covered with small soft protuberances; *rough*, or *uneven*, covered with inequalities of any kind, as opposed to *even*. It may be *prickly; bristly; shaggy*, covered with long, soft, generally white hairs; *woolly*, covered with long, soft, twisted hairs; *hairy*, with long straight hairs; *downy*, with soft fine hairs; *hoary*, with close white hairs extremely fine. It may be *glaucous*, covered with a pale greenish-blue mealiness, consisting of minute particles of the nature of wax, which are rubbed off by the touch of the finger; *striated*, or *streaked*, marked with parallel longitudinal lines; *furrowed*, or *grooved*, marked with larger lines—when the lines become larger and wider still, the stem becomes *cornered*, or *angular*.

Internally, the stem may be *solid*, *hollow*, or filled with *pith*. The *straw*, or *culm* (52), is in general *knotted*, the joints being enlarged; sometimes *jointed*, the joints being small; or it is *geniculate*, or *kneed*, the joints being bent alternately to opposite sides.

MATHEMATICS.

CHAPTER XIV.

APPLICATIONS OF THE RULE OF THREE.

Although the commercial rules of arithmetic appear to be very numerous to the student, when learning the science from the common treatises which are to be met with in our schools, yet they may all be regarded as particular modifications of the rule of three, and reducible to the general method which was exemplified in our last chapter. Instead, therefore, of following the usual mode of subdivision, we shall endeavour to illustrate the common principle by exemplifying its application to questions selected from the various rules,—noting at the same time any remarkable abbreviations by which the processes may be shortened and simplified.

The first of these special applications which we shall notice is the mode of calculating *interest*. By interest is to be understood the profit allowed on loans of money, by agreement of the borrower and lender; and which is *usually* £5 per annum per £100. This is shortly expressed by saying that the interest is 5 per cent.* The following question will explain the mode of calculation:—

* Cent. is a contraction of *centum*, the Latin word for hundred; per cent., by the hundred, or upon each hundred.

What is the interest on £753 at 5 per cent.?

Here, interest being the term sought, we make £5 the third term; and since the interest on £753 must be greater than that of £100, we make this last the first term.

$$\begin{matrix} £ & & £ & & £ & & £ \\ 100 & : & 753 & :: & 5 & : & x \end{matrix}$$

Performing the operation, as stated on the margin, we find $x = £37$ 13s. But, observing that £5 per £100 is equivalent to £1 per £20, the interest sought must be $\frac{1}{20}$ of £753, that is, $£753 \times \frac{1}{20} = £37$ 13s. In like manner, at 4 per cent., the interest would be $£\frac{4}{100} = £\frac{1}{25}$, and $£753 \times \frac{1}{25} = £30$ 2s. $4\frac{3}{4}$d. $\frac{1}{5}$.

When the time is more or less than one year, the readiest way generally is to find the interest for one year, and derive from this the interest for the given time. Thus the interest of £470 for one year at $£3\frac{3}{4}$ per cent., is £17 12s. 6d.; the interest on that sum at the same rate, for *ten* years, is consequently 10 times £17 12s. 6d., or £176 5s. For *half* a-year, the interest will be $\frac{1}{2}$ of £17 12s. 6d., or £8 16s. 3d.

We might regard questions of this sort, however, as examples of the double rule of three. Thus, supposing it is required to find the interest on £26 for 7 years, at $£2\frac{1}{2}$ per cent., we have the annexed statement. Here the rate per cent., being the odd term, is placed above the line on the right;

$$\frac{£26 \times 7 \times 2\frac{1}{2}}{£100 \times 1} = £x$$

and considering the relation of £26 and £100 to $2\frac{1}{2}$, it is clear that the answer with respect to these terms should be less than $£2\frac{1}{2}$, and therefore the £26 is placed above and the £100 below the line. With respect to the time on the other hand, it is equally clear that the answer should be more than $£2\frac{1}{2}$, and therefore the 7 years is placed above, and the 1 year below. By performing the operations indicated, we find $x = £4$ 11s.

This mode of calculation is convenient, when the time is expressed in days. Thus, supposing the question above to be modified as follows:—What is the interest of £26 for 700 days at $2\frac{1}{2}$ per cent.? Here it is obvious that 700 days require a greater answer than 365 days (that is, 1 year); and therefore reasoning as before we have this statement:—

$$\frac{£26 \times 700 \times 2\frac{1}{2}}{£100 \times 365} = £1 \text{ 4s. } 11{\cdot}178 \ldots.$$

From this operation the following rule may be deduced:—Multiply the given sum by the number of days, and by the rate per cent., and divide the product by 365×100, or 36500. But this is manifestly equivalent to the following, which is more simple:—Multiply the given sum by the number of days, and by *double* the rate per cent., and divide the product by 36500×2, or 73,000. Thus the interest of £780 14s. $9\frac{1}{2}$d., for 36 days at 4 per cent., is

$$\frac{£780 \text{ 14s. } 9\frac{1}{2}\text{d.} \times 36 \times 8}{73{,}000} = £3 \text{ 1s. 7d. } \tfrac{1772}{73000}$$

When the borrower keeps the money in his hands for more than a year, without paying the interest upon it as it becomes due, it is clear that he ought at the final settlement to pay interest upon each year's interest for the time he keeps it after it becomes due. This is called *compound interest*, to distinguish it from such cases of *simple interest*, as we have been considering. Such questions may be calculated as follows:—

What is the compound interest on £500, for 3 years, at 5 per cent.?

Here the original sum is	£500
Interest on £500 for 1 year, at 5 per cent., .	25
Amount at the end of 1 year, ...	£525
Interest on £525 for 1 year, ...	26·25
Amount at the end of the second year, . .	£551·25
Interest on 551·25 for 1 year, ...	27·5625
Amount at the end of third year, ...	£578·8125
Deduct original sum, ...	500
Remains compound interest, ...	£78·8125

When the number of years is great, this process is very laborious; on this account, tables showing the amount of £1 for different numbers of years at different rates of interest have been

calculated to facilitate the operation. The mode of using such tables is very simple. Thus, we have one before us, and in the column, headed "5 per cent.," and opposite 3 in the column headed "number of years," we find 1·157625, meaning that £1 becomes £1·157625 in 3 years at 5 per cent. Now, £500 must become 500 times as great; and £1·157625 × 500 is £578·8125, and £500 deducted from this leaves £78·8125, the compound interest as above.

When partial payments are made to account of a debt at shorter intervals than a year, the sums paid are successively deducted from the principal, and the interest calculated on the balances, which arise as in the following question :—

A B granted a bill for £300 to C D, due on the 1st January, on which day he paid £150 of it; on the 3d of March, he paid £50 more; on the 21st of June, he paid other £50, and the balance with the interest on the 12th of September. How much was then due, calculating the interest at 5 per cent.?

		days.	interest.		
Principal, or sum in the bill,	£300				
Paid when due on 1st January,	150				
Balance of principal,	150	× 61	£1	5	1
Paid on 3d March,	50				
Balance of principal,	100	× 110	1	10	1¾
Paid on 21st June,	50				
Balance of principal,	50	× 83	0	11	4¼
Interest due at 12th September,			3	6	7

which, with the balance of £50 due at the date, makes the last payment £53 6s. 7d.

When a debt is constituted by a bond or by the decree of a judge, and partial payments are made at intervals greater than a year, the creditor is entitled by law to apply the payment made by the debtor to the extinction of the interest, before applying it to the principal, and to calculate the interest from the date of each payment on the balances that remain, after deducting the sums paid to account from the amount of principal and interest then due. In other words, the creditor is authorized by law to charge compound interest when the intervals of payment exceed a year.

Supposing that the payment of a sum of money is deferred a year after it becomes due, and has with its interest at 5 per cent. amounted to £336, and that it is required to find what the sum was at first. Whatever this was, it is clear that if we suppose it divided into 100 equal parts, 5 of them must have been added as interest to the first sum, to make £336. If, therefore, £336 be divided into 105 parts, 100 of these are the principal, which we are required to find, and 5 of them are the interest upon it; that is, the principal is $£\frac{336 \times 100}{105} = £320$.

This principle is applied to finding the *present value* of accounts due at future periods. Thus, suppose that A gives B a bill for £336, due at the end of a year from this time, and that B, wishing to obtain the money immediately, transfers it to C; a question arises—How much is the bill worth at the present time? It is clearly not worth £336, and were C to pay that sum for it, he would lose a year's interest by the transaction, and B would gain it. In fairness, therefore, C should only pay to B as much as will with interest amount to £336, at the end of the year; that is, as above shown, £320. The difference, namely, £16, is called the DISCOUNT, and £320 is called the *present value* of the bill due a year hence at 5 per cent discount.

From these examples, the mode of calculation is the following proportion :—

100 + RATE OF DISCOUNT : 100 : : GIVEN PRINCIPAL : PRESENT WORTH.

The DISCOUNT = THE GIVEN PRINCIPAL *minus* THE PRESENT WORTH.

In this case, we have for the sake of simplicity supposed the money to be due at the end of one year; but the period of payment may be greatly longer, and in that case it is necessary to multiply the *rate* of discount by the number of years, and to add the product to 100, to make the first term of the proportion.

When the period, however, exceeds one year, this mode of calculation is inaccurate; it gives a result at simple, instead of compound interest. It is true, we might proceed in this way to find the present value at compound interest, by taking the years in succession, but the process is tedious; accordingly, tables have been calculated to facilitate operations of this nature, in which the present value of £1, due from 1 to 50 years hence, is given, and from which consequently the present value of any sum may be obtained simply by multiplication. Thus, suppose we wish to know the present value of £1500 due 9 years hence at 4 per cent. discount, we find in the table in the column headed "4 per cent," and opposite 9 of the column headed "number of years," the number ·702586, by which if we multiply £1500, we find for product £1053·879, or £1053 17s. 7d. nearly, which is the present value of £1500, due 9 years hence as required. By the mode exemplified above, the calculation and result would be as follows :—

100 + (9 × 4) = 136 : 100 : : £1500 : £1102 18s. 9¾d., a result too great by £49 1s. 2¾d.

The common mode of calculating the discount upon bills, which are commonly payable at periods less than a year, is very simple, although not very correct. Thus, when the holder of a bill wishes to obtain money for it before it becomes due, he applies to a banker to *cash* or *discount* it. The banker calculates the interest upon the sum named in the bill, from the day that the bill is presented to him till it becomes due (which is three days after the time specified in the bill), and deducting this sum pays over the difference as the *proceeds* of the bill. Thus, the *discount* at 5 per cent. on a bill for £50 having three months to run, is 12s. 6d., and the *proceeds* £49 7s. 6d. This mode of calculation favours the banker, but custom has sanctioned it.

Before quitting the subject of interest, we may resolve a question which not unfrequently occurs in commercial transactions. Suppose that a merchant has at different times sold goods to the following amounts, viz., £35 16s. 6d., due 4th May; £21 5s., due 4th July; £46 13s., due 4th August; and £16 8s. 9d., due 4th September; and that on the 6th April, the person wishes to give his bill for the whole amount, at what time should it be made payable?

The rule for this class of questions, which is called the equation of payments, is the following :—Multiply each debt by the time which has to elapse before it becomes due; add together the products, and divide the sum by the amount of the debts; the quotient is the time at which the amount should be made payable. Thus, in the example given, we have

£	s.	d.	debts.		days.		products.
35	16	6, or	£35·825	×	28	=	1003·1
21	5	0, or	21·25	×	89	=	1891·25
46	13	0, or	46·65	×	120	=	5589
16	8	9, or	16·4375	×	150	=	2465·625
		Sum	£120·1625				)10957·975(91 days.

The truth of this rule may be shown by multiplying the sums whose payment is postponed by the times of postponement, and the sums whose payment is anticipated by the times they are anticipated; the products are equal; and this being the case, it is clear that the interest on the sums whose term of payment is postponed must be equal to the interest of the sums whose term of payment is anticipated. The rule, as respects the anticipated payments, is liable to the same objection as that adopted by bankers in calculating the discount on bills, but like that, it has long been sanctioned in practice; and in commercial transactions it is custom which regulates the modes of computation.

The next application of proportion which we shall notice, is the calculation of *profit and loss*. By profit is meant the excess of the selling price above the prime cost, or buying price and charges. Loss, on the other hand, is the excess of the prime cost above the selling price. Profit and loss are generally reckoned at so much per cent. When a merchant is said to have sold goods at 5 per cent. gain, it is meant that he has sold goods for £105 which cost him £100; that is, the price paid for the goods, whatever may have been the magnitude of the transaction, was to the price obtained for them, as 100 is to 105. When he is said to have lost 5 per cent., the meaning is that he has sold goods for £95 which cost him £100; or the prices paid and obtained for the goods are in the ratio of 95 to 100. When, therefore, the terms of questions of this class are understood, the calculations are exceedingly simple. The following instances

illustrate most of the forms under which such questions occur in practice :—

1. Sold at 2s. $9\frac{3}{4}$d. articles which cost 2s. 6d., what was the gain per cent. ?

Here, gain being the term sought, we make $3\frac{3}{4}$d. the gain on 2s. 6d., the third term of the proportion. And, since the gain on £100 will be more than on 2s. 6d., we make 2s. 6d. the first term, and £100 the second.

Thus, 2s. 6d. = 30d. : £100 : : $3\frac{3}{4}$d. = 3·75d. : x = £$12\frac{1}{2}$ per cent.

2. Gained $12\frac{1}{2}$ per cent. on goods which cost 2s. 6d., required the selling price? In other words—supposing £100 to be the prime cost of goods which were sold for £112 10s., what was 2s. 6d. worth sold for at that rate?

Here, the selling price being the term sought, we must make £$112\frac{1}{2}$ the given selling price, the third term; and as 2s. 6d. worth must sell for less than £100 worth, we make £100 the first term, and 2s. 6d. the second.

Thus, £100 : 2s. 6d. = 30d. : : £112·5 : x = 2s. $9\frac{3}{4}$d.

3. Gained $12\frac{1}{2}$ per cent. by selling goods at 2s. $9\frac{3}{4}$d., what was the prime cost? In other words—received £112 10s. for goods which cost £100, what did 2s. $9\frac{3}{4}$d. worth cost at that rate?

Here, the cost price being the term sought, we make £100 the third term; and since 2s. $9\frac{3}{4}$d. worth must cost less than £$112\frac{1}{2}$ worth, we make £$112\frac{1}{2}$ the first term, and 2s. $9\frac{3}{4}$d. the second.

Thus, £112·5 : 2s. $9\frac{3}{4}$d. : : £100 : x = 2s. 6d.

4. A merchant finds, that by selling goods at 3s. 2d., he will gain 10 per cent.; but wishing to give 5 per cent. discount, without diminishing his profit, he wishes to know the price at which he ought to charge the goods in the invoice.

Here, it is obvious, that, in order to retain the 10 per cent. profit, and allow 5 per cent. discount, the quantity sold at £95 must be sold at £100; the question, therefore, is the following :—If £95 worth be sold for £100, what should 3s. 2d. worth be sold for? A selling price is wanted, and, therefore, 3s. 2d., the given selling price, is the third term of the proportion; and as the required selling price must be greater than 3s. 2d., therefore £95 is the first term, and £100 the second.

Thus, £95 : £100 : : 3s. 2d. : x = 3s. 4d.

These questions may be varied at pleasure. We have taken only the case of gain; but the student can have no difficulty in applying the same species of reasoning to cases of loss. He has only to attain a clear conception of the meaning of the question, by translating it into ordinary language; and the order which its terms ought to occupy in a proportion, will at once become manifest.

The variety of the rule of three, called *distributive proportion*, is often of use in mercantile transactions. As a general problem it may be thus expressed :—Divide a given quantity into parts, which shall have the same ratio to the whole number as other given parts have to their sum.

Thus, suppose it required to divide £240 among three persons, in such a way that their shares may be as 2, 4, and 6; that is, so that for every £2 which the first has, the second shall have £4, and the third £6. Here it is plain, that if we divide the £240 into 2 + 4 + 6 or 12 parts, the first must have 2 of those parts, the second 4, and the third 6. Their shares are therefore respectively as 12 parts : parts of a share : : £240 : that share; or

$$£\frac{240 \times 2}{12} = £40 \quad £\frac{240 \times 4}{12} = £80 \quad £\frac{240 \times 6}{12} = £120$$

And the proof is £40 + £80 + £120 = £240

This variety of proportion is applied to the distribution of gain and loss among partners, according to their stocks; the effects of a bankrupt among his creditors, and according to the sums due to them; the amount of an assessment among heritors, according to the valuation of their estates, and similar questions. The principle is obvious. When the time devoted to the business of a company by each partner is equal, and their shares of the capital in the concern are also equal, their shares of the gain or loss ought also to be equal; but it would evidently be unfair that this division should be equal, when one partner had contributed double the sum of another. Thus, if A contributes twice as much as B, and they gain £150, it is clear that A ought to gain twice as much as B; that is, if the whole £150 be divided into three parts, A ought to have two of them, and B one; or A should have £100, and B £50. Similarly, had the partners lost £150 in a transaction in which their interests were as 2 to 1, their losses respectively on the same principle ought to be £100 and £50. The following example will illustrate the mode of calculation more fully :—

Suppose that A, B, and C, engage in an adventure in which A embarks £680, B £580, and C £300; and that their net gain is £520; how much is each man's share? In the first place, it is clear that every £1 of stock ought to have the same share of the gain. Now, since there are £680 + £580 + £300, or £1560 of stock which gain £520, it is obvious that for each pound embarked, there is a gain of £$\frac{520}{1560}$. And, therefore, by the rule of three,

$$£1560 : £680 :: £520 : x = £\frac{520 \times 680}{1560} = £226\tfrac{2}{3} \text{ A's share,}$$

$$£1560 : £580 :: £520 : x = £\frac{520 \times 580}{1560} = £193\tfrac{1}{3} \text{ B's share,}$$

$$£1560 : £300 :: £520 : x = £\frac{520 \times 300}{1560} = £100 \text{ C's share.}$$

In these examples of distributive proportion we have supposed the times during which the money of the partners was employed equal; but it may happen that the stocks of the several partners are employed during unequal periods. In such cases it is clear that the gain must be distributed, not in the ratio of the stocks simply, but in a ratio compounded of the ratio of the stocks and the ratio of the times. If, for example, A and B employ the same sum for the same purpose, but that A's money is employed twice as long as B's money; it is clear that A ought to gain twice as much as B, upon the principle, that £1 employed during a given interval of time, ought to give the same return to each. Again, suppose that A employs £100 for four months; B, £150 for three months; and C, £50 for six months; and that the gain is £80; how much ought each to have of it? Since A employs £100 for four months, he ought to have 4 times as much as if he employed it one month only; that is, as much as if he employed £100 × 4, or £400 for one month. Also, B gains as much as if he employed £150 × 3, or £450 for one month; and C as much as if he employed £50 × 6, or £300 for one month. If then, we divide £80 into (100 × 4) + (150 × 3) + (50 × 6) or 1150 parts; A must have 100 × 4, or 400; B must have 150 × 3, or 450; and C must have 50 × 6, or 300 of these parts. That is

$$1150 : 400 :: £80 : x = £\frac{80 \times 400}{1150} = £27 \;\; 16 \;\; 6\tfrac{6}{23} \text{ A's share,}$$

$$1150 : 450 :: £80 : x = £\frac{80 \times 450}{1150} = £31 \;\; 6 \;\; 1\tfrac{1}{23} \text{ B's share,}$$

$$1150 : 300 :: £80 : x = £\frac{80 \times 300}{1150} = £20 \;\; 17 \;\; 4\tfrac{16}{23} \text{ C's share,}$$

And A's sh. + B's sh. + C's sh. = £80 0 0 the gain.

It must be here observed, that this mode of dividing the profits of a mercantile concern is not always adopted; the manner in which this is to be done is indeed always a matter of special agreement among the partners of a firm. One of the methods in common use, is to calculate the interest (at a specified rate) upon each partner's stock for the time it remains in the concern, to deduct the sum from the whole gain, and to divide the balance into as many equal *dividends* as there are partners; and these dividends, increased by the sums set aside to each as interest, are the shares of the respective partners. Another way is to divide the capital of a company into a definite number of shares, and to divide the whole clear gain by the number of shares; by this the gain upon one share is known, and, accordingly the sum to which each partner is entitled is found by multiplying the gain upon one share, by the number of shares which he holds. Some mercantile concerns, again, are entirely managed by one partner, the other partners merely furnishing capital. In cases of this kind the acting partner is usually allowed a salary which is deducted from the gain, and the remainder is divided among all the parties interested, according to their respective stocks.

We may now conclude our articles on the principles of arith-

metic. We have endeavoured, and we hope successfully, to divest the subject of some of its difficulties, and to reduce the manifold operations which occur in commercial arithmetic, to a few simple rules which are easily kept in mind in connexion with the general principle from which they are deduced. It is true, we have omitted the names of many rules which are to be found in treatises on arithmetic; but no one who understands the principles explained in these articles, can fail to perceive that they are virtually contained in those given. We do not in this, however, include the rules usually given for extracting the square and eube roots; these are yet to be given, and they will form an important part of one of our early chapters on the principles of algebra.

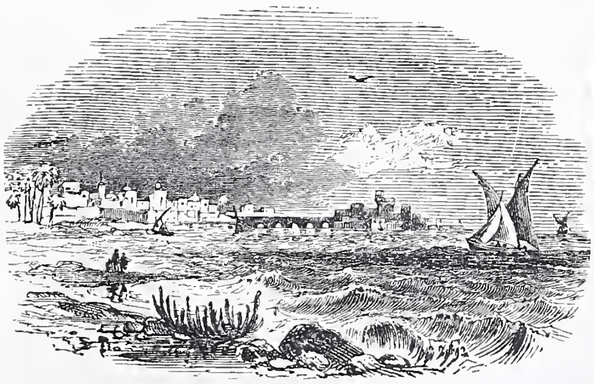
HISTORY.

CHAPTER XIII.

OF THE HEBREWS.

Syria extends from 29° 45′ to 37° 25′ north latitude, and between 34° 10′ and 38° 45′ east longitude. It is bounded on the north by that portion of mount Taurus, now known by the name of the Alma Dagh, and by the ancients as the Amanas. It is separated from Egypt and Arabia by an ill-defined line: its eastern boundary is not more determinate. Its area is estimated at about 70,000 square miles, or about 12,000 square miles less than that of Great Britain.

The river Orontes rises between 33° and 34° of north latitude, and pursues a nearly eastwardly course, till it changes its direction in latitude 36° 45′, and reaches the ocean in longitude and latitude 36°. The Jordan rises also between the 33d and 34th parallels, and a very little to the east of longitude 36°. It flows due south, till it falls into the Dead Sea a little to the south of the 32d parallel of latitude. The valley of the Jordan stretches from the point where it joins the sea, to lat. 29° 45; and indeed the gulf of Akaba, the eastern bifurcation of the Red Sea extending to the cape called Ras-Mahommed, is nothing else than a continuation of the same deep narrow valley. The country between the Mediterranean and the valleys of the Orontes, is broken and hilly. To the east of these valleys it is more mountainous, till the elevations decrease, and finally the country subsides into the Syrian and Arabian deserts. The latter is a wide trackless desert of moving sand, with a few watering-places scattered here and there; but the former is scarcely so inhospitable, affording, after the periodical rains, large tracts of pasture to the wandering Bedouins.



SIDON.

The range of mountains extending from the northern portion of the course of the Orontes, and along its western bank, is abruptly precipitous, and almost Alpine in its features. Its highest elevation, in lat. 34°, forms the Lebanon of Scripture; where, beneath the limits of the line of perpetual snow, may be still seen the remains of the lofty cedars so often mentioned in the Bible, and which Solomon is said to have described. A little to the north, the range divides into two branches. The westmost, of which Lebanon is a peak, gradually decreases in elevation, till it approaches the coast, between the sites of the ancient cities of Tyre and Sidon. The eastern range, called Anti-Libanus, extends to the south, where it divides into two ridges near the sources of the Jordan. The easterly limb of this bifurcation, increasing in altitude to the south, forms the unbroken range which bounds the valley of El Ghor on the east, from the sources of the Jordan to the Akaba. Mount Pisgah, whence Moses, previous to his death, saw the promised land, forms one of its summits. Mount Hor, the burial-place of his brother Aaron, is another. The western boundary of the valley of El Ghor is equally precipitous, but less elevated. Near lat. 32° 45′, it is intercepted by the great plain Esdrælon or Magnus Campus, the field of Egyptian, Assyrian, Mede and Persian, and Roman warfare, and of the Crusades of the middle ages, and the scene of French contest in the present century. Mount Tabor rises in the centre of the plain; here Deborah judged Israel, and its summit is supposed to have been the scene of Christ's transfiguration.

We have mentioned that the southern boundary of Syria was like its eastern, indefinite; but the 31st parallel of latitude, from longitude 32° 45′ to 35° 45′, may be assumed as its proximate terminus on the south. South of this line, having it for a base, is a triangular space, of which the other two sides are formed by the dry valley of El Ghor and the gulf of Akaba, on the one hand; and the salt marshes and sandy plains between Pelusium and Suez, on the other; Ras-Mahommed forms the apex. This tract of country is imperfectly known, except that it is chiefly desert, and is formed by a continuation of the hilly region of Judea. It includes the ancient Edom and stony Arabia; and near its southern termination is Mount Sinai.

The northern portion of Syria, between the Mediterranean and the Euphrates, is formed by the southern declivities of Mount Taurus. It is wild and rugged, and traversed by streams, some of which descend into the lake of Antioch or the gulf of Ains (?); but the greater number lose themselves in the sands of the Syrian desert.

A marked feature of the country yet remains to be noticed. Between the sources of the Orontes and the Jordan, a number of streams have their source in the eastern declivity of Anti-Libanus, which, converging in an easterly direction, form the bright river that waters the fertile garden of Damascus; passing that city, and flowing still towards the east, it is finally lost in a few days' journey, in marshy fens.

In a territory of such limited extent, a great variety of meteorological phenomena, or of vegetable or animal life, in ordinary circumstances, could scarcely be expected; but diversity of elevation and of soil, renders the country a scene of great natural interest, and of incessant change. The rugged declivities of Taurus and the adjacent plains are extremely fertile; as aro also the lands in the immediate vicinity of the Orontes, Jordan, and Pharpar, and round the lower regions of Mount Lebanon.

The temperature of the valley of the Jordan is variable, occasioned by its low latitude, and the cold winds which descend upon it from the snows of Lebanon. In Idumea and Arabia, the air is scorched by the reflection of the burning sands, and the thunderstorm, dissipating the accumulated electricity of the atmosphere, alternates with the tornado, loaded with the suffocating sands of the desert. The high elevations of Lebanon preserve the temperature of northern Europe, while the well-watered plains of Damascus exhibit the luxuriance of an intertropical vegetation. Between Damascus and Jericho there is an interchange of volcanic crag and rich alluvial soil, where the balm of Gilead of old used to flourish; near this we enter upon the sterile regions of the Asphalte Lake or Dead Sea,—denuded of almost all vegetation and animal life, by the salt vapours and bitumen which everywhere exhibit their blighting effects, under the scorching influence of a sultry sun.

Such is the utmost geographical range ever claimed by the children of Israel. It was even a very small portion of this which they possessed during the brief splendour of the Hebrew monarchy. From Dan to Beersheba—from the sources of Jordan, to the extremity of the Dead Sea; and again, from the shore of the Mediterranean, to the summit of the rising ground east of Jordan, this is all the Jews ever possessed of space,—indeed, two degrees of latitude, and two degrees of longitude, more than includes the whole of their territory; and even within this limited space, there were many city districts, which, if they did not retain their independence, were only tributaries, aud

never mixed or became amalgamated with the Hebrew people. Thus, Idumea was a dependency of Israel, during the reigns of David and Solomon, as was also Damascus, and beyond it Tadmor in the desert. The peninsula of Sinai belongs to Jewish history as the scene of 40 years' isolation and wandering, and the giving of the law; as also the declivity of Mount Taurus beyond the Euphrates, as the birthplace of their father Abraham; but all these districts—Idumea, the Damascene Syria, northern Syria, and western Mesopotamia, had only a transient connexion with the central land of Judea. We have a dim vision of the lands beyond the Euphrates, as those from whence the Assyrian hordes thronged into Judea—of the lands "beyond the river of Egypt," from whence the Egyptians and the Egyptian invasions came, and where the days of bondage were endured—of the ocean and its isles, or the region from which the angel of the Grecian empire came rushing in his might; but of all these wide domains the old Hebrew geography knew nothing distinctively. The centre region of Judea is graphically and distinctly pourtrayed, while all the regions beyond Jordan—the Syria of Damascus. Tadmor in the desert, Idumea and Arabia, are faintly and dimly seen in the obscurity of the background. It is this peculiarity of Hebrew geography—its precision within a narrow circle—its growing indistinctness as we recede from the centre of that circle, until the eye reaches the verge beyond which nothing can be seen and all is conjecture, that would, independent of any external evidence, prove its native land—the territory within which it had been accumulated or stored up; nowhere but in the lands around Jerusalem could such knowledge and such opinions have been picked up.

The source of our information respecting the Hebrew nation is derived almost exclusively from the Scriptures of the Old Testament. These are either historical, prophetical, or poetical. The first—in order to ascertain the events of Jewish history, the growth and vissicitudes of the state,—must form the groundwork of our present inquiry. The other two classes of writings must be used as supplementary and illustrative, as incidentally corroborating statements made, or supplying notices of facts omitted; as furnishing intimations of the modes of thought and feeling among the people, in a manner more explicit than a mere historical narrative could convey, and as affording the best test of progress which they have made in knowledge and civilization.

The first question is, what is the age of the Hebrew writings which we now possess? The Hebrew language appears from a passage in Nehemiah to have been spoken after the Babylonish captivity; but it had become only to be understood by the learned shortly after the death of Alexander the Great. The efforts of the Maccabees to restore the national spirit of the Jews, prompted them to restore the old language of their country; but they struggled in vain against the current of events, and, under the dynasty of the Herods, it had altogether ceased to be spoken by the people. The translation of the Jewish canon into Greek,—begun in the reign of Ptolemy Soter, the first of the Alexandrian dynasty, and completed in the time of his successors,—shows that the whole books which compose it, were written before that time, 323 years before Christ. Josephus, who was born about the time of Christ's being put to death, mentions that the translation had been completed long before his day. We have thus the most ample evidence of the existence of these books, and in the very words in which they are now written, previous to the Christian era. Before this time, learned schools existed in Jerusalem, the constitution of which somewhat resembled that of the guilds and corporations of the middle ages. Those admitted were called scholars (הֲבֵרִים); the next grade, that of the younger Rabbis (רַבָּנִים); the third, the rulers or patriarchs (נְאִשׁ־הַיְשִׁיבָה). These enjoyed privileges, and were supported by endowments obtained from contributions of all Jews, whether in Judea or scattered in other countries.

A short time previous to our era the learned at Jerusalem were divided concerning the respective merits of Hillel a teacher from Babylon, and one Shammar a native of Jerusalem, under whom the two factions studied. These academies continued to flourish till Jerusalem was destroyed by the Romans; after which the learned members settled at Jamma, Ziphoriah, Lydda, Cæsarea, but more particularly at Tiberias. These schools continued to prosper till A.D. 130, when their chief ornament, Rabbi Juda the holy, died, and his two most distinguished scholars were induced to seek refuge in Babylon. From this period, the Jewish academies continued on the Euphrates till the 10th century. It is to these schools that we are indebted for the unparalleled careful preservation of their national records, and the sacred books handed down to us. Their learning was almost exclusively confined to the contents, and to the making of faithful transcripts of such writings. We are thus enabled to vouch for the almost perfect accuracy of the transcripts of the Scriptures, up to the period anterior to the birth of Jesus Christ.

We are in fact enabled to vouch for the substantial contents of every chapter, every word and letter having been numbered, and the number registered of each chapter and book, up to the 300th year preceding the Christian era, and are thus brought within 100 years of the government of Nehemiah, who, having rebuilt the city of Jerusalem, returned to the king of Persia about the year 415, A.C. The canon of the Hebrew Scriptures is thus carried back to the rebuilding of Jerusalem after the Babylonish captivity, by a better and more unbroken chain of testimony than belongs to the history of any other ancient writings whatever.

The test by which these writings are to be tried, is their own contents; for the oldest profane historian whose books are extant is Herodotus, who flourished several generations after the return from the captivity. In the first place, there are the historical writings, consisting of

The narrative portions of the Pentateuch, or the five books of Moses.

The books of Joshua and Ruth.

The books of Samuel, Kings, and Chronicles, Ezra and Nehemiah.

In the last two we find recorded, by two of the actors of that most important transaction, the rebuilding of Jerusalem subsequent to the Babylonish captivity. In the books of Samuel and Kings, we find the history of the monarchy to its close at the captivity. In the books of Chronicles, we find the same history is presented in a more condensed form. The books of Joshua, Judges, and Ruth, relate the chief circumstances of Jewish history, from the invasion of Canaan under Joshua, to the commencement of the monarchy. The narrative portion of the Pentateuch contains an account of the creation of the world; of its first inhabitants to the time of Abraham, concerning whom and his immediate descendants, many circumstantial details are given, till their colonization in Egypt; and finally, we have the history of their oppression—their flight—and their long sojourn in the wilderness under the government of their great legislator, Moses.

The books of Ezra and Nehemiah were of course written subsequently to the events they narrate—at what period we may inquire, were the others composed? They appear to be chiefly abstracts of other records, as they are continually making reference to other documents, as the chronicles of the kings of Israel, or those of the kings of Judah, or other books, the names of which had only come down to them as containing a fuller account than they pretended to give. Whether, as has been supposed, these books were compiled by Ezra or Nehemiah, or not, the concluding verses of the second book of Chronicles must at all events have been written after the restoration from the Babylonish captivity; and the concluding verses of the second book of Kings, subsequent to the destruction of Jerusalem by the generals of Nebuchadnezzar. In the 37th chapter of the book of Genesis, it is said,—"and these are the kings that reigned in the land of Edom, before there reigned any king over the children of Israel." Such a sentence could only have been written after a king had reigned over that people; and in Deuteronomy, we read, "there arose not a prophet *since* in Israel, like unto Moses;" *since* plainly intimating the lapse of a considerable time. In the book of Joshua, we are told, that "Israel served the Lord all the days of Joshua, and all the days of the elders that outlived Joshua, and which had known all the works of the Lord." This intimates with certainty the compilation of the book of Joshua at a period subsequent to the death of the last of these, and probably long enough to admit of Israel's apostasy from his first faith. In the 18th, 19th, and again in the last chapter of the book of Judges, the phrase occurs, "and there was no king in Israel in those days," introduced for the purpose of explaining how it was possible that certain events did occur. In addition to these intimations, we find repeatedly in the course of the

narrative two names to a city, with the intimation that one is the now obsolete name of the city known by the other. All these circumstances point out a date of composition, or at least of remodelling of these books, considerably later than the era of the events they record; and in such cases, this later period seems to have been after the monarchical form of government had been introduced into Judea.

We find, then, in the books themselves, no pretensions to their having been compiled by the persons to whose names they are generally ascribed; on the contrary, the most direct indication that they were not. The books of the Old Testament appear to arrange themselves naturally as the productions of two distinct eras in Hebrew literature, namely, that from David to the Babylonish captivity, and that during or subsequent to it.

We must take care, however, not to undervalue the historical records of such as refer to remote events. The books we possess were, in many instances, abstracts from more extensive records, as their frequent reference to the chronicles of the kings of Judah and Israel show. How such chronicles were kept in oriental monarchies, is intimated in the 2d chapter of the book of Esther. "It was written in the books of the chronicles *before* the king." The Hebrews were exceedingly precise as to the preservation of genealogical records; so much so, that Josephus boasts that the archives and registries of the Jews were much more accurate and complete than those of the Greeks or Romans; and, as an illustration, we have in the book of Jeremiah an elaborate record of the purchase of a field, and the preparation of a deed of sale by the scribe, with a view to registration. It was from such sources, and from the books of contemporary writers, not unfrequently mentioned by name, that the abstracts we possess were compiled; nay, there can be no doubt, that there is worked up into the thread of their narrative, the remnants of an earlier age, the language being merely modernized. Of this kind are the decalogue, and some of the Psalms. The fidelity of the abstracts are vouched for by the correspondence of their parallel passages, and in some instances by abstracts which Josephus, Manetho, and others, have given from the contemporary records or chronicles of Tyre, Babylon, and Egypt.

From this retrospect, we see that the history of the Hebrews, previous to the conquest by the Assyrians, falls in regard to its source into two periods; that in which the Jews may be truly said to have possessed a literature; and that in which we cannot say with any degree of certainty that they did. The commencement of the former period cannot be satisfactorily established; but it seems to coincide pretty nearly with that of the Jewish monarchy, and the institution of the school of the prophets under Samuel, who is mentioned, as appointed over them, in the 19th chapter of 1st Samuel. The history of the early period has come down to us in compilations of extracts made during the second. The compilers of these abstracts derived their information from oral tradition, books of earlier writers which they refer to, genealogies, &c. Some of the compositions of this early period are preserved unchanged, save by the modernizing of the language in the historical writings; and some in the book of Psalms. The history of the later period is compiled from similar sources, but the greater part of it by contemporaries. We possess, too, of this era—by way of completing the idea of the people, which a mere narrative must always leave imperfect—the intellectual products of its freer and nobler minds. We possess a lyrical poetry unapproached in power and sublimity, comprehending, along with pieces of a much remoter age, a series of Psalms from those of David down to those composed subsequent to the captivity. We possess the magnificent lament of Jeremiah over his fallen country; and the book of Job, in which the whole philosophy of human life is built up with a depth of insight into the workings of the human heart—a comprehension of the end and aim of life—a gorgeousness and variety of illustrative imagery—and a very whirlwind of poetic fervour, that are yet unequalled in any tongue. From the structure of the language, and the prominent part played by the Chaldeans, the probability is that the author resided in the north-eastern districts of Judea, and lived but shortly, if at all, before the captivity. In the prophets, we have lessons for individual conduct, and for state affairs, at once weighty by their contents, and interesting by the elevated half-poetical structure of the language in which they were delivered; and lastly, in the book of Proverbs, the concentrated observations of life for centuries, of the wisest among the Hebrews. With regard then to this period, we have from contemporaneous narratives of public events, glimpses of private business and manners, enduring monuments of its wisdom and poetical genius.

These are the divisions of Hebrew history according to its sources. Divided in reference to the progress of Hebrew society, it falls naturally into three periods: the first, extending from the call of Abraham to the death of Moses; the second, from the invasion of Canaan to the election of Saul to the monarchy; and the third, from that period to the Babylonish captivity.

Period I, according to generally received chronology, extends from the year 1921 to 1451 before the Christian era. The scene of action during this period is extensive, and lies comparatively seldom in Judea Proper. Abraham leaves Chaldea at an advanced age, and frequently visits Egypt and Philistia. His son and grandson dwell in tents in Judea, and are frequently visitors in other lands. For the rest of the period the scene of action is in Egypt, east of the Nile, and north of the present capital, Cairo, and in the adjoining desert of Sinai, the peninsula and the southern El Ghor—the desert land—" the vast howling wilderness" of stony Arabia. This is the period of the generation and education of a people, who were called to go, in nearly an organized state, to invade and take possession of another country. From the time we are first introduced to Abraham, till that of Jacob and his family settling in Egypt, under the auspices of Joseph, the history is that of wealthy patriarchs surrounded by numerous sons, and ruling over troops of slaves. Their habitations are unsettled, and their occupations exclusively pastoral. Illiterate, and living apart from the crowded haunts of men, they possess abundant leisure; their unruly passions developed themselves with all the power resident in robust constitutions, unrestrained by those laws which regulate the transactions of civilized life; but, side by side with the natural weeds which sprung in so uncultured a soil, grew up gentler virtues, equally spontaneous and devoid of formality. There is something revolting to our conceptions in the amours of Lot and Judah; there is ruthless ferocity in the vengeance of Levi and Simeon; but in return, holy, deep, and enduring love was never pourtrayed in simpler and more affecting guise than in the conduct of Joseph to his brethren, when he bids the hall be cleared that he may allow his tears to gush forth, and throw himself on the neck of his mother's child—his brother Benjamin; and the Hebrew annalist has given vent to a lovelier and more thrilling note of pathos than ever poet conceived. The sturdy devotion of Judah to his boy-brother and his old father, makes ample amends for his other lapses; his sins were those of a powerful and unbridled, not of a depraved, nature. The scenes and the feelings depicted belong to the infancy of the world. The patriarchs walked with God; his voice was heard in the whispers of the breeze, and his influence in the stillness of night, when Isaac meditated at eventide. All heaven was opened on the dreams of the young exile Jacob on the tentless plains of Babel. Their souls imbibed the ennobling doctrine of an all-pervading, just, and benevolent Deity, to whom they might communicate the impulses of their devotion, and in whose protection they might confide. This faith was taught by the patriarchs to their children; and possessed of it they went into Egypt.

A vail rests upon the fortunes of the Israelites, from their entrance till "there arose a king over Egypt that knew not Joseph." By this time they had grown into a people, of the numbers and powers of whom Egypt had become jealous; and all the ignominy of slavery and the cruelty of oppression are endured, till the patriotic principle, burning in the bosom of the adopted child of Pharaoh's daughter—the Hebrew boy whom she had found among the bulrushes of the Nile—led him to avenge their wrongs in a private quarrel, the result of which was his flight into the land of Midian, where, at the back of Mount Horeb, like his ancestors, he communed with his God, and received the high commission under which he became the saviour of his countrymen, and their great lawgiver. In rescuing them from the tyranny of Pharaoh, his task was but half begun: he had to wean them from the fleshpots of Egypt, and fit them—by a long sojourn and almost continual predatory warfare on the surrounding tribes—for the arduous task of conquering the land which had been promised to their father Abraham. Forty years sufficed to eradicate the rebellious spirit he had to encounter, and to train a young brood who had drunk up the tameless energies of the desert with their mothers' milk. He taught them to

march tribe by tribe, and family by family, and to encamp in the same manner. He appointed seventy-two judges to decide in questions between man and man, six for each tribe, with the right of appeal to himself; he taught them a ceremonious ritual and a moral system, the mere practice of which was in itself a worship; he appointed one tribe exclusively for the services of the altar—so far religion might have had a civil or a religious object; but he insisted upon the unswerving worship of the one only God, Jehovah. Thus for forty years did he labour to train his people to habits that would enable them to conquer a country, and to retain it and enjoy it as a home. They were prepared, soul and body; their civil organization was complete against the day they should be in a condition to act. The last slave-born had died in the wilderness; the mission of Moses was accomplished; the God who had commissioned him took him to himself, and the armies of Israel marched onward to combat in his strength, and to be defended by his power.

Period II. extends from 1451 to 1095 before Christ. This period was occupied by the Hebrews, partly in conquering and partly in defending themselves from the vengeance of their enemies, whose territories they had invaded. The entire extirpation of the idolatrous tribes of Canaan, and its extensive possession by the seed of Abraham, formed the groundwork of the undertaking, the substance of the Mosaical ordinances, and the theory of the future government. The *lachesse* of the children of Israel arrested the attainment of the entire accomplishment of the object contemplated. Two and a half of the tribes fought with only half a soul; and the rest, when they conquered enough of space for their immediate purposes, regardless of the wants of futurity, yielded themselves to slothful inaction. The original inhabitants, left in their hilly fastnesses, retained still sufficient strength to avenge at times their wrongs, and to sally down upon their invaders. Kept in terror by these hostile demonstrations, the tribes were deterred from dispersing themselves and taking possession of their allotted portions. Dan dwelt for a time in the borders of Simeon; and when their numbers increased, so as to require ampler possessions, they felt themselves compelled to attack the weaker districts, leaving sometimes a stronger power between their detached encampments; and often, as in the case of Dan, a whole tribe were tempted to forsake the worship of the God of Jacob for that of idols, and to conform to the ways and customs of the tribes in their vicinity. Thus the unity of the nation was broken up; and, scattered and weakened, it became powerless and inert. The faith became dimmed,—and, be it remembered, it was an active and an operative one. It was an habitual consultation of the Divine will,—confidence which inspired the utmost daring, and achieved the most signal victories. But when this—the polar star by which they were to steer—had become obscured, hope became abandoned, and disaster and slavery ensued. "There was no king in Israel in those days, and every man did that which was right in his own eyes;" and though judges were recognised, the law had lost its power; so that in all respects the state of the Israelites, from the death of Joshua till Samuel, may be regarded as retrograding and degraded. Yet did they possess, in the institutions and doctrines of their lawgiver, what, if rightly used, might have kindled them to nobler life. This seed did not always fall by the wayside, or among the brambles. In some corner of Israel or another some noble spirit was ever and anon catching fire at the sacred flame which burned in Shiloh, and revealing in his arm and prowess the might that slumbered in the institutions of Israel. There was always, even in the worst of times, a union kept up among the tribes. Midway between Jerusalem and Mount Tabor was Shiloh the site of the tabernacle. It formed a central point where the union of the tribes could be effected and maintained. The seventy-two, upon whom the spirit of prophecy came in the days of Moses, had never been without successors.

With ordinary exertions, and the occasional victories of impassioned leaders, the Israelites had learned how to maintain the conquest they had won; but this was not enough. They wished themselves consolidated as a state, under regal sway; they coveted a monarch to rule in peace, and lead in battle—a spirit for which their prophet Samuel so severely chid them, yet at last yielded to their will, by anointing the gigantic Saul as king of Israel.

Period III. extends from 1095 to 588 before Christ. The leading events during this period are these:—Saul, for interfering with the priestly office, by offering a sacrifice with his own hands in the absence of Samuel, is denounced by that prophet, who afterwards anoints the shepherd boy, David the son of Jesse, who, on the death of Saul, ascended the throne. He transferred the government from Hebron to Jerusalem, which he had taken from the Jebusites, and at the instigation of the prophet, Nathan, made preparations for the erection of "the house of the Lord;" Solomon his son continued to beautify the city, and to erect the temple to which the tabernacle was removed from Shiloh. Solomon completed the subjection of the tribes intermingled with the Israelites—augmented his kingdom—formed alliances with the Tyrians—and made with them conjoined mercantile speculations to the Red Sea. He formed matrimonial alliances with the neighbouring powers, and caught from the daughter of Pharaoh king of Egypt, in all likelihood, the vanity of rivalling the splendour of her ancestors. The reign of Solomon, however, like most other splendid reigns, was more gratifying to the monarch's vanity than useful to his people. This we are led to infer from the pathetic complaint made to his son Rehoboam on his accession to the throne. "Thy father made our yoke grievous; now, therefore, make thou the grievous service of thy father, and his heavy yoke which he put upon us, lighter, and we will serve thee." The tyrannical answer which the young monarch gave, led to the establishment of a new dynasty over the ten tribes—Judah and Benjamin remaining faithful to the house of David. With this division, the temporal power of the Israelites was broken; one after another, the external dependencies asserted their freedom; Israel and Judah wasted their energies in war against each other, and fell, first the one and then the other, an easy prey to their proud neighbours from the east. This division of the kingdom was also the origin of a religious change. Jeroboam, in order to deprive Jerusalem of its importance as the centre of national worship, erected an altar on Mount Gerizzim. The Levites, however, clung to each other, and to Jerusalem. Jeroboam was obliged to go further than he had originally intended, and to create a new order of priesthood, and a new worship. This thwarted his own purposes. Shiloh had been the restingplace of the ark for ages, and might easily have been rendered a formidable rival to Jerusalem, had the national faith been here administered in purity; but the worshippers of the one God shrunk from bowing the knee to beastly images, and "the abomination" of the surrounding idolaters. The staid and pious of Israel continued, therefore, to regard Jerusalem still as the centre of the national religion; but the spirit waxed faint where no genuine altar smoked to heaven, and when the ritual was divested of the sanction of the government. There were colleges or schools of prophets, however, in Israel still, as well as Judah. They endured persecution; but they clung faithfully to the worship of their fathers. Indeed, the most distinguished of the Hebrew prophets belonged to Israel, and not to Judah. Jerusalem had for them a more than mystic meaning; and as the two kingdoms fell more and more in worldly prosperity, and their monarchs sank deeper in profligacy and profanity, this spiritual faith—this habit of seeing in what had been deemed promises of temporal prosperity, a deeper and a mystic meaning, increased. The fervid piety of David's song—the weighty apophthegms of Solomon, contracted a deeper meaning in their eyes, and kindled in their breasts a higher and a holier enthusiasm. The moral precepts of the Israelites became purer, sterner, and more universal, as the kingdoms approached their fall. The enthusiasm of the prophet bore his rapt soul aloft on stronger pinions—then was he enabled to scan the dread depths of humanity with Job—then were his lips touched with coals of living fire from the altar. His warning voice was heard in an undaunted and unquailing tone above the noise of war, and amidst the assaults of the beleaguering foe; and, when the roof of God's temple crashed amidst devouring flames, high above all was heard the deep symphony of Jeremiah's lamentations—the wail of a tone deeper and more enduring than the love of woman—the voice of an indignation which, strong in the courage of despair, rebuked, as with the stern menace of the angel of death and desolation, the conquerors of the earth in the very drunkenness of triumph!

IRON-FOUNDING.

SECTION VI.

FUEL AND BLAST.

Having described the various forms and conditions of furnace employed in the foundry, it becomes now our business to inquire into the most favourable conditions of fuel and blast.

(1.) It has already been stated, that the quantities of fuel and air supplied to cupolas, which are similarly formed, and which turn out metal at the same temperature, ought to be a constant ratio to one another.

(2.) We found also that, other circumstances being equal, the amount of fuel and air would be proportional to the capacity or horizontal area of cupolas at the tweres; but that as in fact the relative waste of heat by radiation is greater in smaller cupolas than in larger ones, in the ratio of the square roots of the horizontal areas at the tweres, the relative amounts of fuel and of air would necessarily be greater as the furnace becomes smaller, by as much as would evolve the relatively increased waste of heat.

(3.) There is no doubt that the best condition of a cupola, in working order, consists in uniformity of action all over the horizontal area of the furnace.

(4.) To this end, it is agreed to by all, that by disposing of the materials in the furnace in alternate layers or strata, in general uniformly distributed over each other, they are in the most favourable condition for mutually acting one upon the other; and that to facilitate this mutual action, it is of importance that the pigs of iron be broken into smaller pieces, which, as they accommodate themselves more readily to the nature of the furnace, also expose a larger amount of surface to the action of the heat.

(5.) To the same end also, it is evidently of importance to effect an equal distribution of the air among the fuel, that, by combination with it in the act of combustion, a uniform application of heat to the metal may be secured.

(6.) In the air furnace there is an excessive expense of fuel arising from two circumstances. First, from the necessity of draft in the chimney, to induce the air that maintains combustion to pass through the fire. To effect this, there is a necessary expenditure of heat which never serves any other purpose. Secondly, from the separation which is maintained between the fuel and the metal to be fused, the former distributed over the bars of the grate, the latter lying on a distinct hearth; according to which arrangement, the heated air and flame alone come in contact with the metal; while a strong heat is also reverberated from the roof of the furnace all over the hearth. It is curious to contemplate the air furnace as a *nascent* cupola in which there is *no* depth of charge, and all dependent upon confinement by over-arches, and reverberation from them.

(7.) In these two following respects the cupola may be favourably contrasted with the air furnace: First, while the air is *drawn* into the latter furnace at the necessary expense of a large quantity of heat, it is *driven* into the former, independent of the draft, by means of external pneumatic apparatus; the expense of maintaining which is less by a great amount than that of creating the draft by the chimney. Secondly, the charges of fuel and metal in the former furnace are intimately blended, and this to a considerable depth; so that the heat is no sooner evolved, than it is set in combination with the metal, while there is no necessity for waste of heat by the chimney.

(8.) From the nature of the cupola furnace, therefore, the air must be forced into it in sufficient quantity, to maintain the necessary supply of heat, and that too at lateral apertures termed the twere holes. But not only must there be a sufficient quantity; there ought also to be a proper distribution of it over the horizontal area of the cupola. The greater the number of twere holes, therefore, the more easily will this distribution be effected. The introduction of the blast by three twere holes is found amply sufficient for all practical purposes; and, in general, for the smaller cupolas two jets again are adequate to do the work sufficiently.

In order to facilitate the diffusion of the blast, the twere nozzles are made of liberal diameters, from the size of four inches as far as eight inches of diameter. With the same view, the twere holes in the sides of the cupola are, in some instances, made to diverge considerably in passing through the brick lining, forming thereby a funnel mouth to the twere-pipe, as shown in figure 5, and exposing a larger surface of charge at the outset, through which the blast may penetrate. Latterly, in one instance, a still farther alteration to the same purpose has been effected in the form of the twere mouth. It consists in simply flattening and widening horizontally the orifices, so as to present a rectangular area of considerably greater width and depth. It may be easily conceived that the effect of this fan-like jet is to throw the blast over a large horizontal surface within the furnace, and thereby to equalize the combustion. The same general idea is still farther carried out by opening three tweres. at different elevations, in horizontal planes at five or six inches distance between; by which arrangement, the blasts from them will not come into so direct collision one with another.

There are two principal species of blowing apparatus, usually denominated the cylinder or forcing apparatus, and the fan. The leading characteristics of the blasts produced by the two methods are briefly these: that the blast supplied by the cylinder may be pressed to any strength, under the control of the safety valve; whereas, that afforded by the fan is urged only by a certain force arising from the centrifugal motion contributed by the vanes of the machine to the air, which can never exceed what is due to the magnitude and velocity of the fan. These machines will be more particularly described at another opportunity.

(9.) Natural and obvious as the preceding propositions appear to be, it had long been the opinion of iron-founders, that a "stiff sharp blast," or in plain language, a concentrated jet of air, such as the cylinder affords, was indispensable, in all cases, to the economical management of a cupola. The idea might be naturally enough inferred from the existing mode of blowing smelting furnaces; but that the inference is not warrantable is clear, when we reflect that such an intense heat is not necessary merely to remelt foundery pig iron, as to abstract it from the masses of ore in which it is found in nature. In order to increase the intensity of the blast, which was thought so essential to the right development of its effects, the tweres were very much contracted at the orifices, presenting in some instances an area of not more than $1\frac{1}{4}$ inch of diameter. In experimenting in 1810 upon the cupolas of two iron founders in Glasgow, which were blown by the fashionable sharp blast of the day, Mr John Hart, of that city, widened the apertures of the twere holes in one of their cupolas, by simply removing the loam with which they had been lined and contracted, and drew back the blow-pipes, which he fixed out as far as possible without allowing any of the blast to escape. By this means the air was applied to a much larger surface of the charge, and the result was that the furnaces became much more efficacious, reducing the metal much more quickly, with less expense of fuel and of driving power. But there is no necessity for going so far back for evidence, as more modern experience gives ample evidence of the same principle, of the necessity for equal diffusion of air.

Again, when a cupola is supplied with an injuriously concentrated blast, the latter must of course be injected with great velocity, to be in sufficient quantity. Hence the combustion of the fuel, and the consequent evolution of heat, will originate and must exist chiefly in one focus near the tweres. This condition of the blast has a considerable influence upon the quality of the iron, which is rendered harder; and there is no doubt that a portion of it is consumed, and, in company with an important amount of undecomposed air, is carried off by the chimney; whereas, by a gentler and more diffused application of the air, much more complete combustion would take place, as is indeed very obviously realized in the air furnace with its expansive fire-grate. Repeated experiments have been made upon the gaseous products issuing from the funnel-heads of smelting furnaces, by passing a long iron tube down into the charge at different elevations, and collecting the air. In every case, contrary to expectation, free oxygen, or rather undecomposed air was obtained. Nevertheless, when we reflect that highly rarefied air is incapable of supporting combustion, it seems very probable that the heat produced by that portion of the blast which comes into direct contact with the surface of the fuel, will so expand and rarefy the remainder, as to render it incapable of furthering combustion. The case of cupolas is, in this respect, precisely similar to that of smelting furnaces.

(10.) We are aware that there are differences of opinion on the nature of the process of combustion in furnaces. It is remarked in one place, for example, that "the heat developed in common cases of combustion by air, is distributed in three portions: one is communicated to the burning fuel; another is carried off with the volatile products, and a third remains to operate upon any surrounding matter to be afterwards dissipated by diffusion. And, further, when the air is forced into the fire in a strong current, the oxygen of it is brought more immediately in contact with the burning fuel, and there is a certain degree of concentration around that point. This, it is further argued, does not appear to arise solely from the circumstance of more air being forced into the fire—for in the case of an open fire there is an unlimited supply—it seems to depend more upon the assistance given by the mechanical force to the chemical affinities, whose action gives rise to combustion." In illustration of which, reference is had to the case of a common fire when urged by bellows, as the combustion is observably accelerated, and the temperature is raised. It appears to us that this explanation is insufficient to account for the phenomena in question. In the first place, the idea of the mere mechanical force of the current directly aiding the chemical affinities of the elements seems very unphilosophical, considering the great disproportion of their powers. It will not do to cite the cases of an unassisted open fire, and one urged by a blast from bellows. For though, in the former case, there be an unlimited supply of air in the neighbourhood, there is no necessity for its being used as fast as it could possibly come forward. The combustion is comparatively slow, simply because the impure products of combustion do not move so quickly off as to permit a rapid succession of pure air in contact with the fuel. Draft in an open fire is comparatively weak, as the heated ascending gases which cause it are speedily diluted with cold air. But let the fire be enclosed on all sides, so as to form a stove or furnace, being open only at the grate or bottom side for the admission of air, and surmounted by a chimney. In this case it is well known to what a fierce heat and dazzling brilliancy the fire may be raised; and this is to be attributed simply to the rapidity of the change of air caused by the upward motion of the column of gas and air through the chimney, which of course must accelerate combustion. The application of the blast from bellows to an open fire is an artificial stimulus of exactly the same tendency, compelling the products of combustion to move away as fast as they are formed, and thus to afford access to a fresh supply of air to continue the combustion. The mechanical part of the process is precisely the same as what takes place when a current of air blows over a damp surface from which evaporation is going on. The current blows off the saturated stratum of air contiguous to the damp surface, and thus rapidly conveys away the moisture as it arises. The current does not in either case *strengthen* the independent power of combustion or of evaporation; it simply surrounds these powers by circumstances favourable to their operation. In general, then, a sufficient reason for supplying air to cupolas by blast, exists in the necessity for there being always present a sufficient quantity of air to maintain combustion at a proper rate; and it is evident that too much importance has been attached to the mere physical boisterousness of that element.

(11.) These observations must be modified in their application to the inferior kinds of coke; for this substance varies very much in quality. The hard splint coal yields hardly 40 per cent. of coke, while the soft carbonaceous Kilsyth coal, which is the richest in these quarters, yields 70 per cent. of excellent coke. The former kind of coke, as there is indeed least of it, is also of the most impure quality. It is more or less encumbered with calcareous and sulphureous matter, leaving, when consumed, a large quantity of ashes. It is not used in iron founderies but of necessity, except indeed in some of the iron-making establishments, where it is common to remelt for private use, their unsaleable pig-iron: a mixture of iron of all kinds, from No. 1, to the white forge pig; which, one with another, make good substantial castings. In this instance, the inferior compact quality of coke is preferred to the rich and opener quality. This preference is founded upon their relative rates of combustion in connexion with the stubbornness of the harder kinds of iron; these irons require a much longer-continued exposure to heat, to be rightly melted, than the unadulterated softer irons of the regular foundery; and if the rich coke, so appropriate for the latter, were adopted for the fusion of the former, it would operate at a great disadvantage by reason of the rapidity of its combustion; whereas the inferior coke is all the better adapted to the purpose by its relative slowness of consumption, and by that most potent of all reasons, its greatly inferior price. In these circumstances, and in consequence also of the *closeness* of the fuel, a forcible blast is necessary to effect its perfect combustion, apparently by penetrating the pores of the calcareous base of the substance in search of the truly combustible portion. We have seen a branch taken from the blowing machine that supplies the smelting furnaces, conveying a blast of three pounds pressure on the square inch. In consequence of the strength of blast, it was introduced only on one side, as indeed it would, were it sent in off both sides, have been apt to blow the furnace out. The charges of iron also were disposed more distant from the blast, while the coke was lodged principally towards the blast side. The melted iron was thus defended from the direct cooling action of the blast. Though the rich coke by itself would be too quickly consumed at the coarse kind of work just described, it is probable that a mixture of it with coke of poorer quality would be of the most advantage.

Mr. George Thomson, of Glasgow, has published some practical remarks on blast furnaces, which bear upon the point before us, and from which it appears that a considerable variation in the pressure of blast is necessary to suit the different qualities of fuel employed in smelting furnaces, varying from $1\frac{3}{4}$ lbs. to 3 lbs. per inch, the stronger blast for the more inferior coke. So far as this illustrates the subject before us, there is no doubt that differences in the qualities of coke subjected to the blast do, in some measure, account for individual preferences for forcible blasts.

(12.) The foreign matters which are associated with the pig-iron and the coke constitute so much rubbish in the furnace, and are necessary obstructions to the progress of fusion. These substances melted into a viscous fluid by the heat of the furnace are, in this state, termed slag or sullage, and often prove a source of serious inconvenience during the progress of fusion, the existence of which inconvenience depends much upon the condition of the blast. Being at the ordinary atmospheric temperature in its entry into the furnace at the twere holes, it must be heated by the material with which it comes into contact, before it can discharge its functions. This incessant demand for heat, at and around the twere holes, occasions the solidification of the materials immediately above these apertures, which is sometimes developed to such an extent as to create arches of solidified matter, which on some occasions nearly meet at the centre. These arches consist principally of the sullage which is disengaged from the material already melted above the level of the tweres, as that matter solidifies at a higher temperature than the iron. These arches when moderately developed are not injurious to the working of the furnace. On the contrary, in as far as they shield the iron which falls over them from the direct cooling action of the blast, they are positively beneficial. And, seriously, we believe they would have constituted some of the most effective arches in the patentee's cupola, if he had only bethought him of them betimes. But the effects of the cooling action of the blast do not terminate here; for, in some cases, the tweres are entirely blocked up with the overhanging masses of sullage, requiring frequent poking with an iron rod to keep the way open. Such excessive accumulations arise from two circumstances,—an over-concentrated blast, and too large a quantity of diffused blast. The former, it is easy to perceive, is not so readily heated as if the same quantity were thrown into the furnace in a more diffused state from large tweres; and it will tend therefore to throw out shelves of slag. In like manner, the latter, by its excessive quantity, produces the same effect, of which the amelioration is a diminution of the quantity of blast. The more the blast is diffused, the less shelving will result. These facts furnish another argument for the use of a soft diffused blast.

(13.) The contrast of the effects of compressed and diffuse blast, has been strikingly exhibited in the alternate application of Van's patent double-chested force blast and the common blast, by the same twere. The latter blast, while it brought down the iron much more rapidly, maintained for itself a clear passage by the twere holes, bating a slight poking occasionally, while the former blast was inferior in both respects; not melting at more than half the rate of the other, at the same time requiring frequent and forcible application of the iron rod to break down the scaffolding which it was constantly erecting. Both

these results are directly traceable to the kinds of blast employed. The fan blast is essentially uniform in its action, while the other is intermittent, and works in puffs. Now it is easy to see that a certain quantity of air, blown uniformly, would not be so apt to create shelving at the tweres, as the same quantity when driven in dense gusts; as it cannot in the latter case be so readily heated to the temperature of the furnace. There is another point of superiority in the uniformity of the fan blast, as it is thereby enabled continually to follow up its advantages, while the other is intermittent in its operation, and works by puffs: thus it loses much of what it could effect were it constant. In the individual case alluded to, the fan raised a pressure of about 6 ounces to the inch, while the force blast wrought under 12 ounces of pressure, by a twere in both cases of $5\frac{1}{2}$ inches diameter.

(14.) We may see then from the foregoing statements, that the two principal characteristics of a good blast, in all ordinary cases, are spaciousness at the tweres, to diffuse the action of the blast, and strict uniformity of action. Herein, we conceive, lies the gist of the matter. Were a force blast constructed, which should afford a current as unintermittent as the blast from a fan, then they would be equally effective so far as that was concerned. And in fact, a close approximation to uniformity is effected in the force blast supplying the Falkirk furnace, which is constructed on the principle of Van's patent, and consists of six chests, in each of which a piston is driven from end to end alternately, expelling before it the enclosed air. Theso pistons begin their strokes in close succession, so that their inequalities of action are pretty well neutralized among them, though their joint blast is described as still puffy. Another force blast might readily be constructed on tho principlo of chamber organ bellows, which are wrought by several cranks acting in succession. These are well known to issue a very well equalized blast. Yet on a large scale, nothing equals the simplicity, and, in general, the effectiveness of the fan as a blowing machine, for founders' cupolas.

(15.) But again, the superiority of the fan blast is proved by its pliancy, its capability of adapting itself to the number of tweres which it has to supply. A well made $4\frac{1}{2}$ feet eccentric fan, of which the vanes are 12 inches long, by 10 inches broad, and which is driven at the rate of 1200 turns in a minute, will supply from one to six $5\frac{1}{2}$ inch tweres, without much falling off in pressuro at the nozzles, running about 6 oz. per inch of area. Not so the forced blast, whether from cylinder, bellows, or any other source; a definite quantity of air, neither more nor less, must be delivered, whether by one, two, or three tweres. And it is clear that the force of the blast will just be inversely proportional to the number of tweres supplied, supposing these of the same diameter. Where, therefore, there are several cupolas, one or more of which require to be blown according to circumstances, thero is no comparison between the convenience of the fan blast in adapting itself to the work to be done, and the unaccommodating uniformity of the cylinder blast. In Van's patent blast, in which a number of chests are used, the supply may be regulated by setting in motion so many of them as may be adequate to the work to be done; but there is both additional apparatus and trouble incurred.

In connexion with the fact just stated, it has often been observed that the efflux of air from the twere mouths connected with a fan was not the same when blown into the atmosphere, as it was when directed into the cupola; and, moreover, that the velocity of the fan, with the same driving power, becomes considerably increased in the latter case, though this circumstance could of course be fully observed only in situations where the source of power was exclusively devoted to the impelling of the fans. Some *practical* men have imagined these occurrences to have arisen from the blast having been "sucked in" by the draft of the furnace, as it was inferred from the superior velocity of the fan, that it supplied a greater quantity of air. That this, however, cannot be the case, is easily seen on reflecting that the air which issues in a cold state from the twere, encounters instantly in the furnace a very high temperature, which expands it, and contributes along with the solid matters with which the furnace is filled, to diminish the facility of the discharge, and consequently to retard the efflux by the nozzles. The oxygen gas consumed is replaced by a like volume of carbonic acid gas, equally expansible by heat.

The simple reason of the phenomenon is, that the fan has less to do in the second instance than in the first. When more air is allowed to escape, there must more air be driven through the fan; and consequently, the work becomes greater for the power to execute, the immediate effect of which is, that when the source of power is devoted to the work of the fan, there will be a sensible diminution of its velocity, and *vice versa*. But again, in the experiment related in the second last paragraph, the fan was maintained at the same velocity throughout; and accordingly, as it was capable by its revolving motion of creating a certain pressure of 6 ounces per inch, which was unaffected by the actual quantity of air it was allowed to deliver, it was ready to supply a greater or less quantity of blast at a uniform pressure in the simple ratio of the total area of the apertures of the tweres. This it would do to the extent of its capabilities, beyond which the pressure of the blast would be diminished.

The experiment may be still further extended, by entirely closing up all apertures for tho delivery of the air. In this instance, the fan has nothing to do but drive itself, and carry with it a body of compressed air, which is stationary within the casing of the machine. On one occasion, where the fan required the power of two horses working easily to drive it, while blowing a cupola by two tweres; when the tweres were turned to the atmosphere, it took the utmost energies of the animals to drive it; on the other hand, when the tweres and other means of escape were entirely closed, the horses ran forward with the greatest ease, and indeed a single man was able to drive the fan with facility.

From these observations, there occurs another obvions distinction in this, that the amount of efflux from a fan blast is simply proportional to the area of the twere nozzle, and that of course, by enlarging tho nozzle, the quantity of discharge is also enlarged; whereas from a forced blast the quantity is the same for different sizes of nozzles. All tends to show that the great security for the efficaciousness of the fan blast lies in capacity at the tweres.

(16.) The following experiment related by Dr Ure exemplifies the comparative amounts of blast injected into a cupola, and thrown into the atmosphere by the same twere. "Two tweres, one 5 inches diameter, the other $4\frac{1}{2}$, and which consequently presented a total area of $35\frac{1}{2}$ square inches, discharged air into one of the furnaces, from an eccentric fan, whose vanes performed 654 turns in the minute. These two nozzles being briskly withdrawn from the furnace, and turned round to the free air, while a truncated pasteboard cone of $3\frac{1}{2}$ inches diameter was substituted for the nozzle of $4\frac{1}{2}$ inches, whereby the total area of efflux was reduced to 29·3 square inches, the velocity of the vanes continued exactly the same. The inverse operation having been performed; that is to say, the original nozzle having been replaced, and both of them smartly replaced in the furnace, to discover whether or not the moving power had changed in tho interval of the experiment, they betrayed no perceptible alteration of speed. From the measures taken to count the speed, the error could not exceed three revolutions per minute, which is altogether unimportant upon the number 654.

It follows, therefore, that when the vanes of the fan have tho velocity of 654 turns per minute, the expenditure by two nozzles whose joint area is $35\frac{1}{2}$ square inches, both blowing into a furnace, is to the expenditure which takes place, when the same nozzles blow into the air, as 35·5 is to 29·3; that is, a little more than four-fifths."

(17.) We have heard it admitted, that a fan blast melts metal much more rapidly and economically in large cupola furnaces, than the cylinder blast, while the latter blast was observed to do the service better for small cupolas; it being found that the former blast was apt to blow them out by choking at the tweres. This objection, however, is not essential to the fan blast; and it leads us to remark, that the proper proportions of the areas of twere nozzles for furnaces of different capacities have been totally neglected in general. Referring to the table already given of the duties of several cupolas, we find that a 6 inch twere is made to supply a cupola of not more than 2 feet diameter, with a $3\frac{1}{2}$ ounce blast, while a $5\frac{1}{2}$ twere supplies a large 5 feet cupola with a 4 ounce blast. The absurdity of this proportion is evident, and there is no doubt that a great quantity of fuel is lost in heating tho superfluous supply of air. It is no matter of surprise, therefore, that in some instances the loss by this means should be so excessive, as to stop the progress of fusion. The cure ought to have been executed either by sufficiently reducing tho area of

the nozzles, or by weakening the pressure of tho blast, by a sliding valve or otherwise. The virtue of the cylinder blast would be its weakness, which adapted it to the wants of a small cupola.

(18.) The quality of the iron melted by the fan blast is generally allowed to bo superior to the quality of that brought down by the force blast. The fan seems to have a mollifying influence upon the iron, and is always preferred for melting metal to be employed in casting hollow goods, and thin flat ware. But it has been complained in one quarter, that the rims of pulleys cast from fan-blast metal, almost universally cracked in the eooling, while they rarely gave way when made from the force-blast iron. We suppose it is well known, that the peculiar liability of pulley rims to give way arises from the tension to which they are subjected in cooling, owing to the premature contraction of the rims over the arms, while the latter are yet hot. The stronger the iron, therefore, the better will the casting endure. But the fan, while it enriches the iron, also lessens its absolute strength, and it appears to us that the simple remedy would be, to throw harder iron, or to inject less air into the furnace.

(19.) It has been stated in favour of the cylinder blast, that the machinery employed in its production is less troublesome, less noisy, and less expensive, as regards both occasional repair and driving power, than that employed in producing the fan blast. This may be true of the fan, as it has been sometimes constructed ; and when we take into consideration the great velocity of the moving parts immediately engaged in the production of the blast,—it is obviously only by very carefully constructed and well-proportioned workmanship that due justice is done to its merits. In fan machinery, simple as it is, we have observed that in some instances, monthly, weekly, and even triduan repairs have been incurred, in consequence of a want of exact balance among the parts of the fan upon its axle. With careful management in the first construction, this source of annoyance may be entirely removed. Another great fault consists of injudicious methods "of bringing up the speed," with too great rapidity, namely, with a view to which, it was necessary to make use of as few intermediate shafts as possible, which of course requires that large pulleys shall drive proportionally smaller pulleys than if the rate of the reduction of speed were more moderate. On the other hand, the experience of many founders proves that, by moderately attaining the speed by the use of a greater number of intermediate belt pulleys, repairs of any importance are not incurred for months and even years. The great evil of too rapidly raising the speed is the aptitude of tho belts to slip upon the drums ; for when slipping occurs, especially among the slower parts of the motion, the belt is subjected to violent and sudden strains, caused by its unequal hold upon the rim of the drum. The usual remedy for this condition of things is to apply rosin and pitch to the acting surface of the belt to give it a hold. But the best plan is to employ spur gear in the slower parts of the motion, and broad belts and pulleys of conveniently large diameters for the rest. The following are the dimensions of a very excellent fan motion. It is driven directly from the engine shaft, which moves at a rate of 50 revolutions per minute. This shaft carries a spur wheel of 4 feet diameter, driving a smaller wheel of 2 feet ; on the axis of which is a belt pulley of 4 feet diameter, driving a 20 inch pulley, on the axis of which is a second 4 feet pulley driving a 12 inch pulley on the fan axle, which performs 960 revolutions per minute. The fan is 4 feet diameter. From 900 to 1200 turns per minute, is the usual rate at which fans are driven ; and from 4 to 6 ounces per square inch, is the ordinary pressure of the blast produced by them.

(20.) Figures, 12, 13, 14, represent various forms of fans. In general, they consist of a central spindle, upon which are hung either five or six arms, meeting on an eye at the centre, through which the axle is passed, and by which they are fixed to the axle. Upon each of these arms a square blade, generally of sheet iron, is firmly fixed, by rivets or bolts ; the assemblage of blades constitutes the propelling agents. To render them effectual, they are incased in a round box, accurately adapted to them, having a central opening in each side for the admission of air, and an opening in the circumference for the expulsion of the air, with a short passage in continuation, to connect the air passages leading to the furnace. By the rapid revolution of the blades upon this axle, a strong current of air sets in at the centre, and is propelled along the air passages to the cupola.

Fig. 12, represents the form of fan that has been much used formerly, and still is in use to some extent, we believe. This figure is taken from a fan in work, which is driven by the intermediate gear above described. It has six east-iron arms with blades affixed, *e*, &c. These arms, it will be observed, are set in tangents to a circle of ten inches diameter, which has the effect of setting back the blades to an angle of 10° with the radius. The dark outline of the figure *a b c* shows the form of the cheeks between which the blades are suspended, with the central aperture *a a*, for the admission of the air ; the outline also represents the *cover*, or casing, that closes in the machine all round, fixed air-tight in grooves formed on the inner sides of the cheeks. The cover is open only at *d*, which is the aperturo by which the air is thrown out.

In this fan, there are two things worthy of remark ; first, that the blades are set back at an angle of 10° with the radius ; which is with the view of effecting the more direct expulsion of the air. This idea, as we shall afterwards have occasion to notice,

Fig. 12.

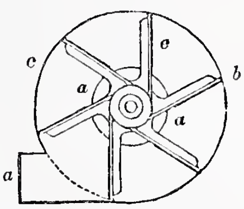
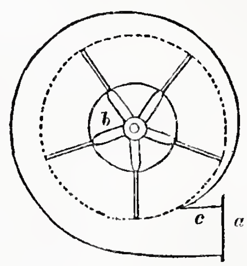


Fig. 13.



rests on a misconception of the mode in which the air is acted on in its progress from the central opening to the circumferonce. Secondly, the cover is set close all round upon the circle in which the fan revolves, with the view of confining the air between the blades, till its exit at the passage *d*. This also rests upon a misconception ; for it is clear that the greatest possible quantity of air would pass through the fan were it not confined by the cover ; but of course the difficulty would be to collect it into one stream. Now, in confining the blades so closely with a eover, their free action is checked everywhere but at the orifico *d*. As soon as each blade passes the corner of this passage, the air which it draws in will be collecting and condensing by the force of centrifugal motion, until it arrives opposite the opening *d*, when it will be driven out. Whereas, were the cover made to recede gradually from the circle of the blades, as in fig. 13, beginning at *c*, the corner of the opening, so as to form a clear winding passage to the exit at *d*, it is evident that the air could now be thrown into this passage at every point, and would be carried along as in the general stream, by dint of the velocity it acquires, and the pressure behind it. And accordingly, by the results of experiments it is found that this *eccentric* form of fan, as it is called, is much the more efficient.

Fig. 13, is a vertical section of the eccentric fan as usually constructed. The wedge-shaped space indicated by the outline, which is the eover, and the interior dotted circle, within which the blades revolve, shows the gradual recedure of the cover from the blades, beginning at the corner *c*, and terminating at the outlet *a*.

A still further improvement has been suggested, on considering the yet imperfect manner in which the air is conducted to the opening at *a*. If we examine the progress of a particle of air from the edge of the opening *b*, where it enters to the extremity of the blade, by which it may be acted upon, we shall find that the line in which it moves is the resultant of a series of forces, continually varying in intensity and direction, as tho particle recedes from the centre. In fact, the line which it in general describes will be a curve springing from the opening *b*, and erossing the dotted circle at a considerable angle. It is evident, then, that the air, on being expelled beyond the bounds of the dotted circle, will be directed against the cover, and suffer deflexion before it can go in with the current that sets round the fans towards *a*. Indeed, in its confluence with this genoral current, it must create eddies with it, and in this way also retard its progress. It is, therefore, advisable to have some means of preserving to the stream all the velocity communicated to it by

the blades. The most obvious method of effecting this seems to be such an arrangement as is represented in figs. 14 and 15.

Fig. 14, is a side view of the fan, and fig. 15 is a cross vertical section ; a is the escape aperture, b is the cover considerably more expanded than in fig. 12, c the point at which the current originates, e the blades, and n n, a series of cutters not seen in fig. 15, are set round the dotted circle, and fixed between the cheeks. These cutters are curved, and are so placed that they may receive the air on their interior edges in the tangents to their curvatures, by which precaution the air should glide uninterruptedly upon their interior surfaces, and ought to be deflected in the direction of its motion, so as to join smoothly in with the general current when it leaves the outer edges of the cutters. In fig. 15, the axle, with the bushes at the extremities are shown in section. It will be observed that the journals of the axle are unusually long ; this is with the view of dispersing the great amount of friction to which they are subject, by running in their bearings at such a high velocity as is usually communicated to the axle. Unless these parts be very well fitted, and the frame-work of the arms and blades perfectly balanced and firmly fixed upon the axle, the greatest difficulty is experienced in preventing the "firing" of the rubbing parts. It is easy to see that if there be but a very slight want of equilibrium in the machine ; or in other words, if the centre of gravity of the moving parts do not lie in the axis of revolution, there will be an amount of centrifugal force created, during revolution, proportional to the eccentricity, which must be borne by the axle.

In figs. 14 and 15, the arms are made to sustain the blades in radii of the circle ; for it has been proved by experiment that radial blades are, *cæteris paribus*, the most efficient in expelling the air. In fig. 13, the arms are of wrought iron welded to the centre, and twisted about at the root of the blades, so as to

Fig. 14.

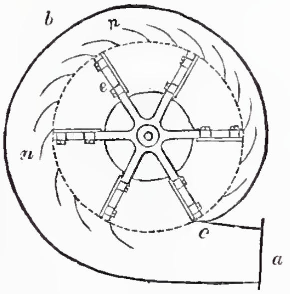
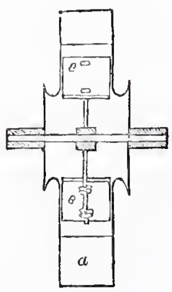


Fig. 15.



present the edges foremost of the parts next the centre, while the sides of their outer parts are turned to support the blades. In fig. 14, the arms are uniform, and the blades are fixed to them by countersunk bolts and nuts.

According to experiments by Dr Ure, the quantity of air delivered by an eccentric fan, as represented by fig. 13, may be calculated approximately by the following rule : multiply the total area of exit by seven-eighths of the velocity of the tips of the blades, the product is the cubic measure of the quantity delivered ; and generalizing his calculations of the absolute force required to drive a $4\frac{1}{2}$ feet fan, we have the following general formula for fans of the same construction ;

$$\frac{a\,v^3}{457600} = \text{the horse power necessary to drive the fan.}$$

a, being the total area of efflux for the blast, and v, being seven-eighths of the tangential velocity of the tips of the blades. This formula, which is said to agree pretty well with experiment, is derived in the following manner :—

Let v, = seven-eighths of the velocity of the tips of the blades in feet per second ; a, = the area of section of the discharging orifices in square feet ; then $a\,v$, = the cubic feet discharged per second, with the velocity v ; and since a cubic foot of air weighs nearly $\frac{1}{13}$th of a pound, $\frac{60\,a\,v}{13}$ = the weight of air in pounds per minute acquiring the velocity v.

Now let h, = the altitude through which a heavy body must fall to acquire the velocity v, then $v^2 = 2gh$, (g being equal to $32\frac{1}{6}$ feet, the velocity acquired by a heavy body in falling through $16\frac{1}{12}$ feet in a second ;) therefore $h = \frac{v^2}{2\,g}$; and thus the mechanical force required must be that which will raise a weight $\frac{60\,a\,v}{13}$ through a height h, in a minute ; that is, it is equal to

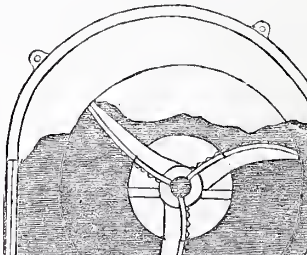
$$\frac{60\,a\,v}{13} \times \frac{v^2}{2\,g} = \frac{3\,a\,v^3}{13\,g} \div 3300 \text{ in horse power} = \frac{a\,v^3}{457600}.$$

Hence, for the same fan, the power varies directly as the cube of the velocity ; and the rule is, when expressed in words, to multiply the total area of efflux in feet at the tweres by the cube of seven-eighths of the velocity of the extremity of the blades, and divide by 457600 : the quotient is the number of horse power required.

For example, a $4\frac{1}{2}$ feet eccentric fan, revolving at the rate of 1200 a minute, discharges air by two tweres of $5\frac{1}{2}$ in diameter—what is the rate of discharge, the pressure at the tweres, and the power required to drive the fan ?

In this instance, the area of each twere is $5{\cdot}5^2 \times {\cdot}7854 = 23\frac{3}{4}$ square inches, therefore a, = $47\frac{1}{2}$ inches = ·33 square feet. The fan performs 20 turns a second, and its circumference is 14 feet ; thus the velocity of the tips of the blades is 280 feet per second, and therefore $v = 245$. Then the rate of discharge is $245 \times {\cdot}33 = 80{\cdot}85$ cubic feet per second. As for the pressure of the blast, it may be found from the formula $v^2 = 2\,gh$; from which we have $h = \frac{v\,2}{2\,g} = 933$ feet of air ; or if we take air to be one-900th of water in weight, $h = 12$ inches of water = 8 oz. pressure per inch. Again, $a\,v^3 \div 457600 = 10\frac{1}{2}$ horse power for driving the fan when the twere nozzles are exposed to the atmosphere. But from a former experiment by Dr Ure, mentioned in section (16,) it appears that a $4\frac{1}{2}$ feet fan propelled the air with a velocity of 133 feet per second, into a cupola by two tweres, whose total area was $35\frac{1}{2}$ inches ; and it was found that the power necessary to drive the fan, when blowing into the furnace, was to that required when the same nozzles blew into the air, as 4 : 5. If we infer the same proportion for the present case, then 4-5ths of $10\frac{1}{2}$ will give 8 horse power as that required to blow the fan into a cupola. This result is considerably above what is usually understood to be the necessary power. More complete experiments are wanting on the whole subject of fans.

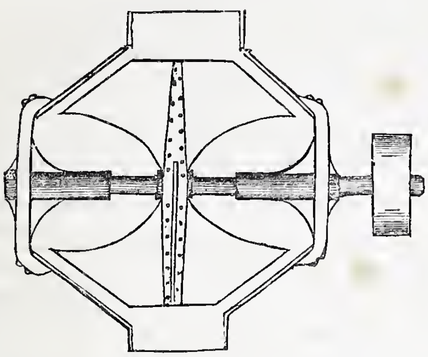
Fig. A.—Elevation, with part of the side-cover removed.



Messrs. Lyon, Lawson, & Co., of Glasgow, in 1843, constructed a new fan for blowing smithy fires, which, we believe, is in more than one respect superior to the ordinary fan, fig. 13. This improved fan is shown in figs. A and B. The peculiarity lies in the cut of the blades, which are so turned off at the centre as to catch the entering air more effectually, and are also tapered away on the outer edges, to which the form of the casing is adapted, the contracted circumference of which constitutes the internal air passage. The taper form of blade was adopted on the supposition, that as the air is considerably condensed by the action of the blades, it naturally occupies less room, *while moving at the same velocity*. The advantage of this improved fan is proved by the results of its action, by which we find that its capabilities are nearly doubled upon those of the ordinary fan,

while the disagreeable noise attending the latter fan is wholly evanished; a fact which, of itself, affords a strong argument in favour of its excellence. This fan is about 2 feet diameter, and makes 850 revolutions per minute: it supports a column of water $3\frac{1}{2}$ inches high, which indicates a pressure of $2\frac{1}{3}$ oz. on the square inch.

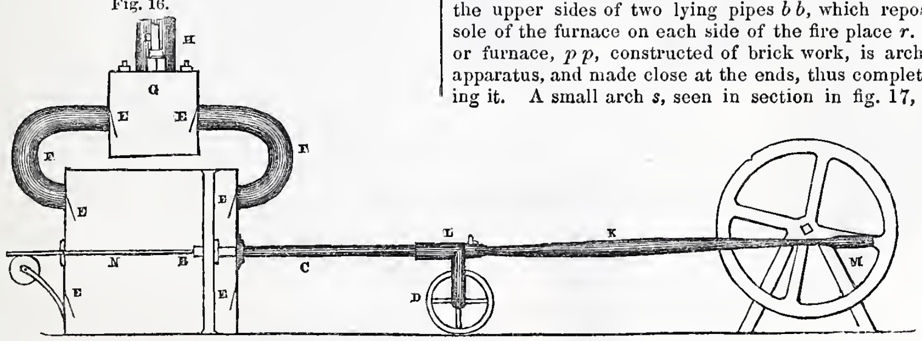
Fig. B.—Plan, showing the form of the fan-blades.



(21.) The most usual method of generating a forced blast is to place the blast cylinder under the unoccupied end of the beam of a steam-engine, and to connect its piston-rod with the beam by means of a parallel motion, similarly to the steam-cylinder at the other end. The blast cylinder is furnished with valves at the upper and under ends, by means of which its piston is enabled at every stroke to expel a cylinder full of air. It is evident, that the blast taken directly from the cylinder, as is generally the case, must be intermitted in its action, from the variable motion of the piston and its total stoppage at each stroke. An intermediate air-vessel is sometimes used, and softens, to a certain degree, the irregularities of the blast.

Vaughan, or Vans' patent blowing-engine was patented about the year 1820. This machine, of which fig. 16. is a vertical section, consists of two oblong square boxes, having valves at each end for the admission of the air, in which square pistons move. Only one of these boxes is shown in section, as the other is exactly behind it. B is the square piston which is moved from end to end by the rod C, bearing on the wheel D, which runs on a race levelled for it. The box is provided with valves, &c., for the purpose of admitting the air; and thus, by the alternate motion of the piston, the blast is forced through the pipes F F, into the chest G, from which it is prevented from returning by the upper valves E E, into which also the blast from the other box is conveyed in the same way. In this manner the blast is continually forced into the chest G at equal intervals, whence it is conveyed away by the pipe H. I is a loaded valve, placed on the top of the chest G, by which the air can be let out when the blast is too strong. K is a connecting-rod, jointed to the end of the piston-rod, and also to a crank at M, from the shaft of which the moving power is supplied. N is a small rod attached to the piston, passing through the bottom of the chest, and running on a small wheel. By means of this rod the piston is always preserved at right angles to the top and bottom of the chest. The cylinder is twenty-eight inches square; the length of stroke is twenty inches; and the machine makes seventy double strokes per minute, delivering therefore from the double-chest 1289 cubic feet of atmospheric air per minute; a deduction, however, ought to be made on account of the re-expansion of the compressed air left at the end of each stroke in the spaces allotted for clearance.

Fig. 16.



Between the double chests, the action is rendered more uniform, though it is decidedly puffy. In article 13, we have already noticed its merits. The action of the blast is improved by the adoption of six chests, as has been done at Falkirk Iron Works. The pressure of this blast is twelve ounces per inch. We are persuaded, that, had a fan been employed for the production of the blast, that furnace would have exhibited results of its action superior to what it does. It was thought that a fan blast would, perhaps, not answer for passing through the heating apparatus for want of pressure; but a four feet eccentric fan, driven at the rate of 2000 a minute, ought to create a blast of fully $\frac{3}{4}$ lbs. per inch of surface, which it seems would be sufficiently strong for the purpose. The principal novelty is the heating apparatus by which the blast is heated to a temperature of 442° Fahr., the melting point of tin, before passing into the cupola. Fig. 17 is an elevation of this apparatus, in which the front wall is supposed to be removed to show the interior. Fig. 18 is a plan of the same, supposing the top of the furnace removed. The apparatus consists of a series of fifteen pipes, *a*, &c., of the form of an inverted V, the ends of which are inserted and made tight in two corresponding series of facets cast upon the upper sides of two lying pipes *b b*, which repose upon the sole of the furnace on each side of the fire place *r*. The stove, or furnace, *p p*, constructed of brick work, is arched over the apparatus, and made close at the ends, thus completely enveloping it. A small arch *s*, seen in section in fig. 17, but omitted in the other figure for the sake of perspicuity, is thrown over the fire place, and abutting on the lying pipes, its object being to protect the bent pipes from the direct action of the fire. It is numerously perforated all over, so as to form passages by which the flame and heat of the fire may ascend into the heating chamber. Several of these are seen in the section of the arch. A flue, omitted in the drawing, extends along the top of the chamber, communicating with it at intervals by openings, and terminating in a chimney stalk forty feet high. The lying pipe *b*, to the right of the figures, is produced at both ends to the exterior of the furnace, and its length is divided into two parts by a tight division just between the eighth and ninth vertical pipes. To the front end is connected the upright pipe *c*, which comes directly from the blowing machine. From the opposite end a pipe *d d* is laid off to the tweres, terminating in three upright branches *e*, *e*, *e*, to which are affixed the nozzles *n*, *n*, *n*, which are directed into the furnace *o*, shown in horizontal section at the tweres. The cast-iron square bottom plate is shown with four square snugs at the corners for receiving the ends of the columns which support the upper portion of the cupola.

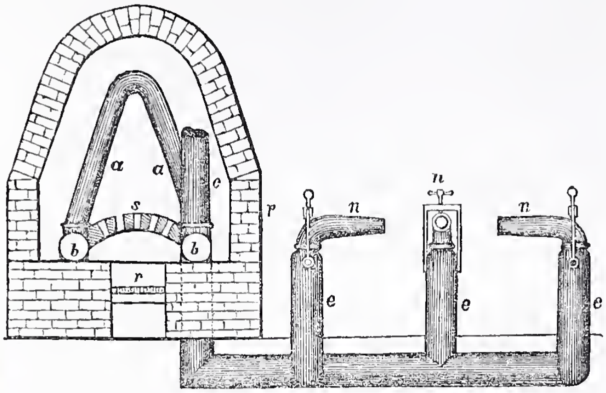
The division in the right hand lying pipe separates the vertical pipes into two series of eight and seven respectively. The air, coming down the cold-blast pipe, and along the first part of the lying pipe, is forced through the eight arched pipes into the other lying pipe, along which it flows, and it thence returns by the other seven pipes into the first lying pipe, whence it is led off to the tweres.

The cold-blast pipe, the lying pipes, and the pipes leading to the tweres, are all of them twelve inches in diameter. The arched pipes *a* are sharply elliptical in their cross section, presenting an area of nine inches by two. Heating surface is thus largely developed, and secures the thorough saturation of the air with heat. To preserve the pipe *d* from exposure to cold and damage, it is led under ground in a brick conduit, and is enveloped in sand, which is covered in with iron plates.

The heating apparatus consumes one ton of dross per day.

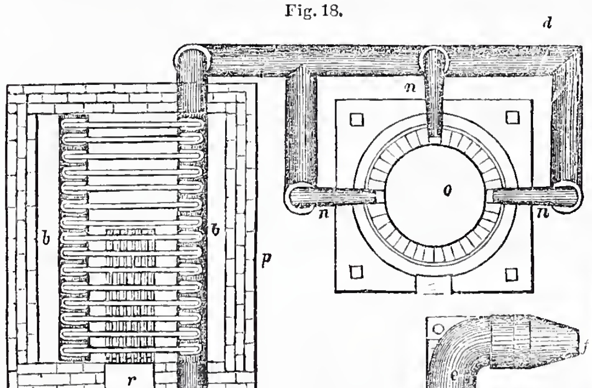
There is, as we are informed, no comparison between the saving of coke, due to this apparatus, and the expense of its maintenance. We can believe this on reflecting that Kilsyth coke costs at present 21s. per ton, whereas dross costs but 3s. per ton. The heating of the blast, too, ought to do away with the annoyance of choking at the tweres. It is said, also, to shorten the process of melting, though we think this has not yet been sufficiently ascertained; and to improve the quality of the iron

Fig. 17.



Figs. 19, 20, 21, respectively represent a side elevation, plan, and vertical section of an ordinary conduit and twere pipe, for the conduction and delivery of the blast. *a* is the conduit, a square passage, constructed either of boards of wood nailed together, or of brick lined with Roman cement, built under ground when the fan is removed some distance from the furnace. It is connected at *b* to the nozzle of the fan, and terminates at the other end in a square plate *h* at the surfa of tho ground, the

Fig. 18.



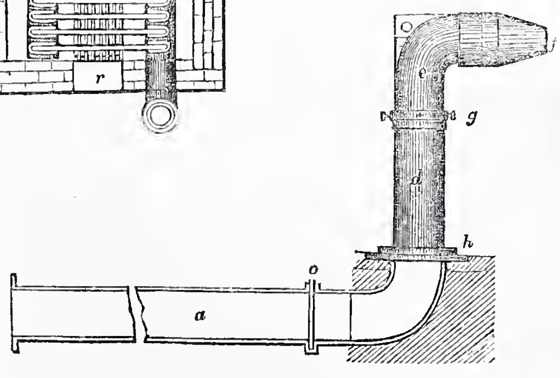


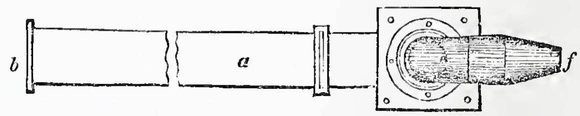
Fig. 19.

centre of which may be about two feet from the outside of the furnace. A slider *c* is adapted to shut off the blast, or modify its action as may be required. *d* is a ten-inch cast-iron pipe, half inch thick, bored cylindrically throughout its length, to receive the nine inch sliding piece *e*, turned exteriorly to fit easily the piece *d*, so as to slide in it to different levels. These pipes are made air-tight by rings of leather inserted in grooves turned on the pipe *c*. This pipe, bent horizontally at the upper end, receives upon it the sliding twere pipe *f*, made of either sheet or cast-iron, and contracted at the nozzle to the necessary diameter. *g* is a loose wrought-iron ring, embracing the pipe *c*, and having three or four pinching-screws, by which it is made fast upon this pipe, and is thus made to hold it at any level, by sitting on the end of the pipe *d*.

A novel arrangement of fans has lately been put in practice by the Messrs Ruthven of Edinburgh, with the view of applying that species of blowing machine to smelting furnaces. A series of three eccentric fans are so arranged that the same current passes through them all successively; that is, the external air having been drawn in by the first fan, is expelled into the centre of the second fan, whence it is again expelled in the same manner into the third fan, which finally sends it into the furnace. All the three fans are four feet in diameter, and have twelve inch square vanes; they are all driven at the rate of 2000 turns per minute. The power expended in driving them is three times that required to drive one fan, while the ultimate pressure of blast produced is also tripled upon that created by the first fan, which is stated to be fully twelve ounces to the square inch; the final pressure being nearly $2\frac{1}{2}$ lbs. on the same area. The power required to drive this apparatus is stated to be not more than that spent upon an equal quantity of cylinder blast.

(22.) A set of furnaces for the preparation of coke are frequently attached to iron founderies, where a convenient situation can be commanded. That variety of cubical coal, denominated the

Fig. 20.



coking coal, is best adapted to the purpose of making coke. Small as its fragments may be, it readily cements even by a moderate heat, into one mass, by reason of the abundance of bitumen in its composition. This is named by eminence the smithy coal, as it readily runs into a vault by the action of the heat, forming a shell or dome for the confinement of the heat. The same quality adapts the small cubical coal, when prepared by slow combustion, to act as coke for cupolas, blast furnaces, locomotive engines, and in fact wherever an intense heat is necessary.

The coking of small coal is performed upon vaulted hearths, not unlike bakers' ovens, but with flatter roofs. Of such kilns, several are placed alongside one another; and where there is no limit as to space, they are usually made nearly circular.

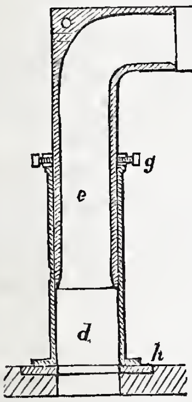
Figs. 22, 23, 24, are respectively a plan, sectional elevation, and front elevation of part of a range of coking ovens. They are arranged in either single or double lines as may be convenient, and discharge the products of combustion into a horizontal flue, which terminates in a chimney. Each oven is nine feet wide, and ten feet deep from back to front; *a* is the mouth, three feet wide outside; *b b*, are the entrances into the flue; they may be shut more or less completely by horizontal slabs of fire brick, to modify the draught of air; *c c* is the flue, leading to the chimney *d*; *e*, fig. 23, are the entrances of the ovens into the horizontal flue, the direction of the draft being indicated by the arrows; *f* is a bed of concrete upon which the furnace range is built; *k*, *k*, fig. 24, are the doors for closing the entrances, consisting of fire-brick built into cast-iron frames; they are raised and lowered by means of chains and counterweights. *i*, *i*, *i*, are the bracing hoops for binding the furnaces.

These furnaces, alternately, are ordinarily charged with $2\frac{1}{2}$ tons of coal when quite dry, being spread evenly over the hearth at a depth of about two feet. A few burning cinders may be placed beside the charge to begin the combustion, or a wisp of straw may be thrown in on the top of the heap, as it will take fire by radiation from the dome, (which is in a state of dull ignition from the preceding operation, as the labourer always observes to refill the ovens immediately after the last charge is withdrawn); in either case, the flame soon spreads and inflames the smoke then rising from the surface, by the reaction of the hot sides and hearth upon the body of the coal. Thus the smoke is consumed at the very commencement of the process, when it would otherwise be most abundant, there being an abundant

supply of oxygen from the air, as the door and the vent are then open. No more smoke, therefore, is discharged from the top of the chimney, at this the most sooty period of the process, than is produced with an ordinary kitchen fire.

The door is now let fall over the opening of the oven in front, and at the same time the opening in the vent is also closed. The door is further rendered tight by clay luting applied round the edges, except at a small part left open at the centre of the bottom edge to admit a small and constant current of air. The coal gas, or other gas, supposed to be generated in the slightly heated mass beneath, cannot escape destruction in passing from it. As the coking of the coal advances slowly and regularly from the top of the mass to the bottom, only one layer is affected at a time, and in succession downward, while the surface is always covered with a stratum of red hot cinders, ready to ignite and consume every particle of carburetted or sulphuretted hydrogen gases which may escape from below.*

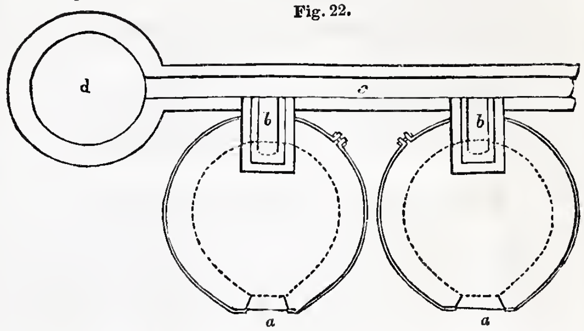
Fig. 21.



The coke being perfectly freed from all fuliginous and volatile matters, by a calcination of about forty hours, the stages of the process being all along observed through a small hole in the door for the purpose, the door is completely closed up. Then commences the process of aggregation, by which the coke, which has been up to this point infirm and friable, forms hard prismatic concretions throughout its depth, resembling a mass of columnar basalt. This is allowed to proceed for twenty-four hours, at the end of which the coke has considerably cooled down, after which the door is unloosed and raised clear of the entrance, and the damper removed. An iron bar is then suspended across the mouth of the furnace, by swing chains hung on both sides of it. Over this bar are slid long iron rods hooked and shovelled at the ends, which being projected into the oven, the former loosens the mass of coke and makes way for the latter instrument, by which the material is drawn out over the iron sill. A quantity of water is thrown over the still hot coke, which hardens it and cools it more rapidly.

Good coals, thus treated, yield from 60 to 70 per cent. of an excellent coke, weighing about 14 cwt. per chaldron. It is observed that a twenty-four inch thick bed of small coal deposited in the coking furnace, shrinks about three inches in depth. The lateral shrinkage seems to cause the separation of the coke into columnar masses as already mentioned. Coke has a compact structure, with considerable metallic lustre, and it has sometimes a semi-crystalline appearance. Carbon is the principal element of coke, which is reckoned the purer the less mixture there is of earthy matter in its constitution. Coke is an excellent conductor of heat, which qualification is of great importance in inducing a speedy equalization of combustion under the peculiar circumstances of the cupola.

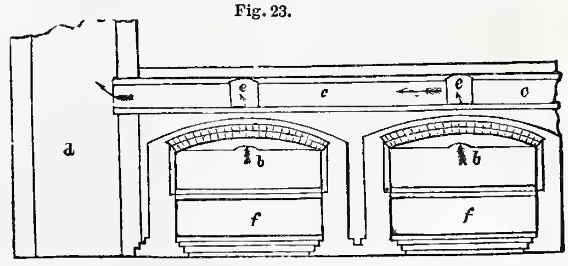
Fig. 22.



The small coal used for the manufacture of coke ought to be as dry as possible ; when damp, it is apt to *choke* in the furnace ; that is, the process of calcination is likely to be interrupted in its progress downward, leaving raw coal at the bottom in its original condition. When wet, of course the less coal must therefore be laid in. The management of the draft, too, is a point requiring considerable attention. The size of the opening under the door, usually about twenty square inches in calm weather, must be reduced in blowy seasons. If the rate of combustion be too great, it burns off the bituminous matter, which is the most valuable ingredient ; when too much diminished, the coal is only partially coked. The chimney may be as wide as it is convenient to have it ; for its only use is to carry off the volatile products of combustion beyond the reach of the workman. Inasmuch as it tends to strengthen the draught, greater attention on the part of the workman is requisite to the management of the furnace.

In England, we believe a double door is sometimes erected, there being a foot of space between the outer and ordinary door and the inner one. This inner door is temporarily built of bricks laid on one another without mortar, thus affording by the open interstices free passage to the draught, regulated as before by the opening at the outer door. This arrangement completely confines the heat, which, when a single door is used, escapes in great quantity. It is of little importance further than that it is more agreeable to the workman, and may accelerate the process.

Fig. 23.



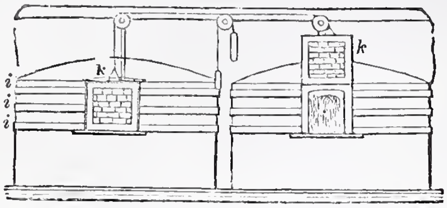
In one coking establishment attached to a large foundery, the happy idea of manufacturing their own gas for lighting the works, has been well developed. The furnaces are fitted up with a series of gas retorts into which gas coal is introduced. On exposure to the action of the heat arising from the furnaces, the contents of the retorts are affected in the usual manner; gas is given off and collected, and at the end of the process, the cinder left in the retorts is taken out and used as coke with the rest of it. It is said also that the gas arising from the contents of the oven itself is preserved and collected unconsumed, though we cannot see how this can be done without an additional furnace as a source of heat. The proprietors, we are told, save, by this means, an annual expense of £100.

(23.) Fig. 25 is a side elevation of a loam mill, used in foundries for the preparation of loam. The mill represented in the drawing is capable of supplying loam for the manufacture at a mean rate of 10 tons of loam castings per day; on an emergency, it

* It was once customary for neighbouring proprietors to interdict such coking establishments as a nuisance, more especially those in the service of railway companies. Several years ago, the London and Birmingham Railway Company's range of furnaces were interdicted on such a plea; and, likewise, we believe those in the service of the Edinburgh and Glasgow Railway Company were interfered with on the same plea. In the former case, a parcel of affidavits, says Dr. Ure, were procured from sundry chemical and medical men. Two of the former, who had not entered the premises, but had espied the outside of the furnace range at some distance, declared "that the coking process, as performed at the ovens, is a species of distillation of coal!" How rashly, ejaculates Ure, do impractical theorists affirm what is utterly unfounded, and mislead an unscientific judge! That the said coking process is in no respect a species of distillation, but a complete combustion of the volatile principles of the coal, is manifest from the above account of its progress. The greatest mass, when inclined in the downward order already explained, cannot emit into the atmosphere any more of the gases mentioned than the smallest heap; and therefore the argument raised, on account of the magnitude of the operations, is altogether fallacious.

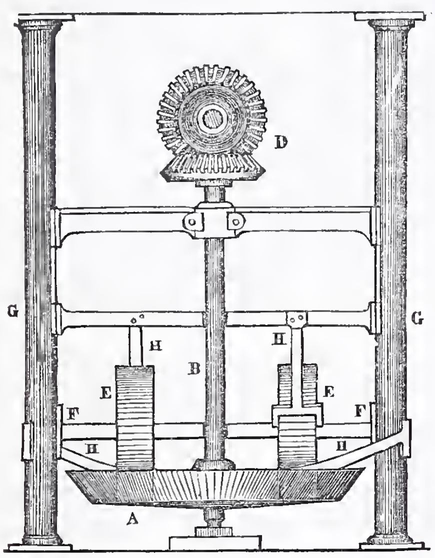
will supply loam sufficient for 15 tons of casting. It is estimated that an average expense of 1 ton of loam is incurred for 1 ton of casting, and 1½ tons of brick for the same work. This mill turns out, at the ordinary rate of working, 40 barrowfuls

Fig. 24.



of loam of 5 cwt. each in a day. A is the circular trough or saucer in which the loam is made. It is hung on an upright shaft, B, which makes 13 revolutions in a minute, and runs in a step, C, at the bottom; the trough is 5 feet diameter at the bottom, and 9 inches deep. A pair of rollers E, E, which stand in the trough, are turned by the trough itself; they are kept stationary otherwise on their axle, the extremities of which slide in vertical grooves F, F, fixed upon external framework, that the rollers may accommodate themselves to the inequalities of the charge. They are 31 inches diameter by 9 in width, and are made either of cast-iron wholly, or of stone hooped with iron. A series of scrapers H H H H, are fixed externally, and are for the purpose of gathering together the straggling portions of the loam under the rollers. D, are the driving wheels, by which the motion is communicated from a horizontal shaft; G,G, are two upright cast-iron columns serving for *points d' appui.*

Fig. 25.



M. DE PRONY'S FRICTION DYNAMOMETER OR BRAKE.

ARTICLE I.

FORM EMPLOYED BY CAPTAIN MORIN IN EXPERIMENTS ON WATER WHEELS.

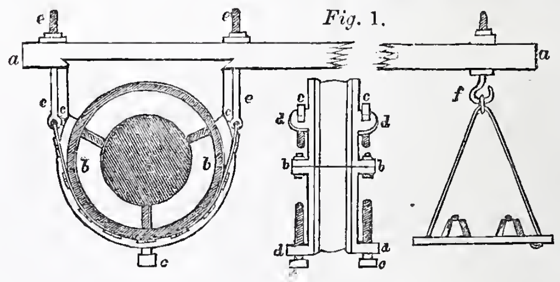
The Friction Dynamometer—more commonly known among our engineers as Prony's Brake or Friction Strap—is by far the most simple, elegant, and effectual means which we possess of testing the actual mechanical power developed in prime movers. The principle which it involves is the well-known fact, that in all machines some part of the motive power is consumed by friction, and that this friction may, at will, be so augmented as to consume the whole power of the machine. Thus, by gearing to a steam-engine, or other prime mover, a train of wheel work of sufficient dimensions and extent, it would be possible so to multiply the friction of the moving parts as to use all the power developed by the mover, and leave none for application to useful purposes. But from this it manifestly follows, that where the friction produced consumes the whole power, if the amount of that friction could be by any process correctly ascertained, it would furnish an accurate measure of the power of the machine, the retarding force being equal to the motive power.

In 1821, M. de Prony's attention was directed to this principle, and, by similar reasoning, happily realized the cheap and effectual instrument already named; and which we have no hesitation in characterizing as one of the most elegant and useful inventions which France has bequeathed to practical mechanics.

The original form of dynamometer devised by Prony has undergone several modifications by other engineers, to suit the particular circumstances of the machines subjected to experiment. That employed by Capt. A. Morin of the French artillery, in his extensive and admirable series of experiments upon the water-wheels of the principal large works using water-power in France,* is represented in the annexed drawings, figs. 1 and 2. He acknowledges to have borrowed the chief peculiarities of its construction from that used by M. Egen, in his experiments upon the hydraulic machines of Westphalia.†

REMARKS BY M. MORIN ON THE FRICTION BRAKE.

I. *Description of the Brake with a Moveable Ring.*—The apparatus (represented in the annexed figures 1 and 2) consists of an annular collar of cast-iron, formed in two parts, and united at *b*, *b*, by ears, with bolts and screws. The inner diameter of this collar is 31·49 inches, to allow of its being placed upon the large



Form of Friction-brake employed by M. Morin in testing the power of Water Wheels.

shafts of wheels. Its thickness in the middle, and on a breadth of 6·3 inches, is 1·19 inch; but in practice this may perhaps prove insufficient, as will be subsequently shown. On the sides, the collar is strengthened by a rim or flange of 1·19 inches projection. This is intended to render it more rigid, and to prevent the friction-band which is placed upon the pulley from escaping laterally. The outer surface was turned with care, so that it might be set exactly concentric to the shaft of the machine to be tested.

II. *Manner of centring the ring or collar of the Brake.*—To allow of the collar being set truly and with ease upon the shaft, it is provided with six square-headed screws *c c c*, disposed symmetrically on its exterior. These screws pass through the projecting ears *d d d d* (fig. 2), and have about 10 inches of their length cut with a thread. They answer thus for most cases, but for shafts under 15in. diameter they are too short. This inconvenience is remedied, when the shafts are of wood, by making the screws press against intermediate wedges of sufficient thickness; but when the shaft is of cast or wrought iron, the apparatus

* These experiments were made between the years 1828 and 1835, and a detailed account of them was published at Metz and Paris in 1836, under the title of "*Expériences sur les Roues Hydrauliques a aubes planes et sur les Roues Hydrauliques a augets.*" In that publication M. Morin has briefly but explicitly developed the theory and application of the *brake*. From this part of the work the succeeding paragraphs of this article are in substance translated.

† These experiments were made, by order of the Prussian government, in 1828 and 1829. An account of them was published at Berlin, in the German language, in 1831.

must be mounted, previous to its being fixed, upon a cylindrical or hexagonal tube of sufficient size.

The ring being placed upon the shaft, the outer surface may easily be adjusted by manœuvring the centring screws; nevertheless, this operation being of great importance to the success of the experiments, it must of necessity be done with the utmost attention to accuracy.

Although the collar may be centred with facility, the effort which tends to make it turn with the proper motion about the shaft being frequently very great, the screws, when very *long set*, are apt to be bent. When the shaft is wood, they are likewise apt to furrow its surface and become loose. To avoid these inconveniences, it is necessary, after centring the collar, to wedge it up strongly on the shaft, disposing the wedges in pairs, so that their outer faces may be always parallel to the axis. Three or four pairs of wedges thus arranged are usually sufficient to fix the collar solidly; but it is necessary to be careful in the operation of wedging, not to make the outer surface take an eccentric curvature. To avoid all risk of this, the thickness of the ring, in an apparatus of the size here described, ought to be more than 1·19 inch. This, however, was always found sufficient when the proper precautions were attended to.

III. *Friction-band.*—The collar being thus mounted concentrically upon the shaft, it is ready to receive the friction-band. This is an articulated flat chain, composed of eight plates of sheet iron, $\frac{1}{8}$th of an inch thick, by 3·94 inches broad, jointed or hinged together by pins of $\frac{1}{5}$th to $\frac{1}{4}$th of an inch in diameter. The chain is curved to a radius slightly greater than that of the collar, for the purpose of allowing the angles of the joints to retain the grease, and any other extraneous matters which may get between the rubbing surfaces. The chain is terminated by two half links, made stronger at the upper ends, in which are formed the females of the hinge to receive the two plates and bored parts of the two large bolts *e*, *e*, of $23\frac{5}{8}$ inches long, by $1\frac{1}{2}$ inch in diameter, to which they are joined by small bolts of half an inch in diameter.

By means of this construction of chain, a more systematic distribution of the pressure is obtained upon the surface of the collar, than can be had with a band of strong sheet-iron.

IV. *Lever of the Brake.*—The bolts *e*, *e*, pass perpendicularly through the arm *a a*—which is a piece of pine tapering from $7\frac{9}{10}$ to $5\frac{1}{2}$ inches square between the extremities. The ends of the bolts *e*, *e*, which pass through the lever, are screwed and furnished with large nuts which retain them securely. The under side of the arm receives, by notching, a cushion of hardwood, the under surface of which is cut out cylindrically to receive the collar upon which it rests. A hole is pierced through both the lever and the cushion to receive the oil necessary for lubricating the surface of the collar when the apparatus is in use.

At the extremity of the lever is a hook *f*, for a scale-pan to contain the weights by which the brake is loaded. This hook ought to have two screws, one above, and another below, or one screw above and the projection below, between which the lever may be fastened, so that the suspension may not be deranged by shocks, in the course of an experiment.

The essential parts of this brake are, then, the collar, the friction-band, the cushion, the hook, and a key or wrench for fastening the screws—the whole not exceeding 500 lbs.

V. *Mode of using the Brake Dynamometer.*—To ensure success in experiments with this apparatus, it is proper at first to examine if the wheel, whose action is to be tested, be properly centred in relation to the external form, and coincidence of its centre of gravity with its axis of rotation. It may also be necessary to restore the buckets to a good state, and to cause them to have the same play in relation to the sweeps of arrival and escape, and to the walls. If, then, the wheel be not in equilibrium about its axis—which can easily be observed—counterweights must be added interiorly, on the proper side, to re-establish the equilibrium. That done, and the bearings carefully examined and greased, the brake may be adjusted upon the shaft in the manner described. The lever is placed in a horizontal position, its extremity passing between two cross-bars, firmly fixed as points of support, at sufficient distance asunder to allow it to oscillate above and below the horizontal line, (which is its true position,) through an arc of two or three degrees in an invariable manner. This disposition is much preferable to detaining ropes, sometimes employed for the same purpose, as it completely obviates all the danger which might be occasioned by the accidental increase of the friction of the friction-band and of the collar, in consequence of which the lever would be raised and (its effective length, and consequently its power, becoming less and less the more it ascended above the horizontal position) would tend to be dragged round with its load in the general motion of the wheel. It has also the further advantage of giving to the experiments absolute precision—if we consider the lever of the brake to be really in equilibrium when it oscillates lightly between its two supports.

It is, however, necessary to be satisfied that the inertia of the masses in motion does not develop, during the continuance of the experiments, a power sufficiently great to make a sensible impression on the results; and we arrive at this by counting at several trials successively, the number of revolutions performed in a given time—(say one minute). When this is found to be constant, we may be satisfied that the motion is uniform, or at least, regular; and that for the interval considered, the total quantity of work developed by the inertia must be null.

The apparatus being mounted, a number of experiments can be made in succession, and in very little time. This facility is of importance, as it enables us to make experiments corresponding to the different openings of gate, and heads of water, under which the machine can act. It also enables us, by varying the load upon the brake, to determine the velocity under which the machine acts most advantageously. For this purpose it is proper, in each series of experiments, to make the load vary progressively from zero, up to that which stops the machine, or at least as near to this last as may be attained without danger.

VI. *Limits of the power which the Brake can equilibrate.*—The dimensions of the brake described are such, that it could be applied to measure the useful effect of a great number of prime movers. But since the pressure of the friction-band, and, of course, its friction against the collar, ought to augment with the power of the machine; that is, the power to be measured, it attains in some cases a superior limit which cannot be passed without the surfaces of contact abrading themselves—which, besides injuring the apparatus, deprives the results of their desired precision, by producing shocks and irregularity in the oscillations of the brake-lever. As this is always to be avoided, it is preferable, in cases where the prime-mover is of great power, to employ a collar of corresponding diameter, so that the friction may not reach the abrading intensity. To determine what this diameter should be, it may be proper to observe, that in all experiments where the brake described was employed, in spite of every precaution in applying unguents of oil, hog's lard, and the like, the band and jaw abraded whenever the friction on the circumference required to be from 1 to $1\frac{1}{3}$ tons in order to equilibrate the power of the machine operated upon (that is, about $\frac{1}{4}$th of a ton per inch of the breadth of the friction-band). By estimating, therefore, about the maximum power which the machine can exercise under the most favourable circumstances, it is not difficult to determine the radius of jaw, so that the friction which will serve to measure this assumed maximum power shall be within the limit value indicated by the relation just stated. How far we may safely deviate is shown by the following calculation, which establishes, at the same time, the theory of the apparatus.

VII. *Theory of the Brake Dynamometer.*—When the brake is mounted and fixed (on a water-wheel shaft), and the lever and load are held in equilibrium, that is, oscillate lightly between the points of support, and when the head of water and supply remain constant, and the wheel moves at a uniform velocity, it is evident *that all the available work, or power, transmitted to the wheel, is consumed by the friction of the friction-band upon the collar.* Therefore calling

P' the *mean disposable power* at the distance R from the axis of rotation,* which in cases where the brake is mounted on the same shaft with the water-wheel, is the outer radius of this wheel;

V, the velocity of the circumference R;

S, the friction produced at the surface of the collar; and

r, the radius of this surface,

* This mean power P' is evidently less than that which is transmitted to the extremity of the radius R, (and which we may designate by P) on account of one part of it being employed in overcoming the friction on the axis of rotation: this is the reason why I distinguish P' by the name *disposable power.*—*Morin.*

then we have at each instant $P'v = S\frac{r}{R}v$, or $P'R = Sr$. But, on the other hand, the lever of the brake, as well as its load being maintained in equilibrium by the friction S, if we designate by

F, the total load of the brake ; and by
L, the horizontal distance from the point of suspension of this load, to the vertical plane of the axis of rotation :

Then we have $FL = Sr$, and consequently, $P'v = F\frac{L}{R}v$.

But $\frac{L}{R}v$ is evidently the path that would be described by the point of suspension of the load in a second, if the lever moved with the shaft on the wheel. Hence it appears that *the product of the total load* F *of the brake, by the path that the point of suspension tends to describe in one second, measures the quantity of available power transmitted to the shaft on which the collar is placed.*

It may now be remarked, that when we have estimated approximately the maximum value of the power P,′ the limiting value S being fixed at 1 to $1\frac{1}{2}$ tons (for a brake of the size described), it is easy to determine the size of the radius r, which the collar of the brake should have, in terms of these quantities, and of the arm of the lever R of P′.

VIII. *Estimate of the power consumed in the passive resistances.*—The product $P'v = F\frac{L}{R}v$, which measures the quantity of available power of the machine operated upon, is the result most important to be known for industrial comparisons ; but in those experiments where it is intended to value the construction of a receiver of power, the effects of the action of the water, the influence of the velocity, and of the other circumstances of the motion of the machine, or when we have not been able to place the brake on the same shaft with the wheel, it is necessary, in order to obtain the total power realized by the receiver to add to this quantity of work $P'v$, that which is consumed by the several other parts in motion. For if considerations foreign to the mode of action of the water have rendered it expedient to give to those parts considerable dimensions and weight, they may consume notable quantities of power, of which the value is entirely independent of the good or bad arrangement of the receiver, and which must absorb a part of that which is really *utilized.*

Although M. Morin thus found it necessary, in developing the theory of the brake, to include the elements in a general equation, it is not requisite, in determining practically the power of a prime mover by this apparatus, to resort, in the computations, to any other than the elementary rules of arithmetic. So simple, indeed, are the operations, that the experiments may be cast with the utmost facility by every artisan, as we shall endeavour to show in a succeeding article on this simple apparatus.

ON THE PROPERTIES OF THE CRANK,

AND THE VARIOUS SUBSTITUTES PROPOSED FOR IT IN STEAM-ENGINES.

ARTICLE I.

PROPERTIES OF THE CRANK.

Till very lately, the contrivance of a mechanism which would generate power, was thought quite a legitimate problem. Government fostered this belief by a proclamation which it has not yet recalled, offering a tempting reward for its solution. The error has finally passed into the hands of a few wrong-headed individuals, ignorant alike of the history and of the principles of mechanics ; but we have only passed from one extreme to the opposite. We rarely meet with candidates for the proffered reward which is so temptingly held out to the discoverer of the perpetual motion ; but we are still infested by another fallacy, which notwithstanding its opposite tendency, belongs to the same category. We are no longer told that mechanism *per se* can generate power ; but the opposite opinion, that machines, independently of the friction of their rubbing parts, are capable of destroying power, has still numerous and intelligent adherents. Thus we are perpetually informed of the great and needless waste of power which results from obliquity of action in the moving parts of a machine, and are not unfrequently called upon to examine cumbrous and expensive contrivances for rendering these actions direct, and for recovering—it may be more than recovering—the power believed by the inventor to be unnecessarily thrown away. From this to the conception of a perpetual motion, is only a step ; for admitting a machine to be capable, independently of friction, of destroying power, we might rationally expect that the inverse action of the same machine would be capable of generating it. Both doctrines are equally inconsistent with the fundamental laws of mechanics, and with that law of mechanism which informs us that in every combination of the ordinary mechanical powers, supposed to be divested of friction, the efficient power is of precisely the same value at all points, understanding the efficient power to be the force multiplied into the velocity.

To develop this principle more fully, it is necessary to refer to the law of *virtual velocities.* This law informs us, that if two weights balance each other when suspended from unequal arms of a lever, that they are to each other inversely as the lengths of these arms ; and if the lever be made to vibrate on its fulcrum, the distances through which the weights move are directly as the lengths of the arms from which they are suspended ; so that if each weight be multiplied into the distance through which it moves, the two products are equal to each other. Thus the descent of 1 lb. through 10 inches would, for example, be accompanied by an ascent of 10 lbs. through 1 inch ; so that whatever is gained or lost in intensity of pressure, is lost or gained in distance. The same law holds true of combinations of pulleys, and also of the inclined plane and bent lever, although its application to these cases is not so obvious. It is also true of any combination of these mechanical elements ; for if in any machine we induce motion, it may be found that the force transmitted, combined with its velocity, is equal to the force applied combined with the distance through which it has advanced. This is true, however ill-contrived, and however ill-constructed the machine may be ; it delivers over the whole, and exactly the whole amount of force which put it in motion. Part of this force it expends in overcoming the friction of the rubbing surfaces including the resistance of the air, and gives up the rest as effective power to accomplish the particular purpose for which the machine is intended.

If, then, this principle be correct, it follows that in every machine composed of the ordinary mechanical powers, the quantity of power developed, that is, the dynamical effect of the moving force, is the same at all points, and that the power is transmitted without any other change in its value, than is caused by the loss resulting from friction. In a mechanical point of view, the inventor can profitably direct his attention only to two objects,—economy in the material and labour necessary to the first construction of the machine, and the diminution as far as practicable of the effects of friction. Were all friction avoided, it would be matter of absolute indifference by what means the required changes of motion might be produced ; it would then be of no moment whether we employed the reciprocating or the rotatory steam-engine, whether we adopted long or short connecting-rods, whether we used the crank, or the sun and planet wheels, further than the mere expense of workmanship is concerned. Beyond this, and the comparative amounts of friction, we have absolutely no criterion for estimating the superiority of one mode of construction over another.

It would not be difficult to establish the principle involved in these broad statements by general reasoning applicable to every possible combination of machinery ; but we shall, in the mean time, confine our attention to the condition of the steam-engine crank —the ground-work at present of much pernicious fallacy and needless controversy. This may seem inconsistent with the simplicity of the crank ; for no machine can possibly be more elementary in its character, and we might suppose could be more easily understood, and give rise to fewer doubts respecting the nature of its action. So simple is it that we can hardly reckon it an addition to the axle of which it forms a part : it is merely a *crook* upon it, and appears to have been the earliest contrivance for the purpose of converting a revolving into a rectilineal mo-

tion and the reverse. It is figured in the old machines of the Egyptians, the Chinese, the Greeks, and the Romans; and it has been employed to move the pistons of the cylinders of water-pumps since the time of Aliotti in precisely the same way as it now moves in the steam-engine. A radical misconception has, however, arisen regarding it, and a multiplicity of crude and abortive contrivances have been proposed to supersede its use—all less elementary in their character, and every way inferior in point of practical application.

To show the grounds upon which this misconception rests, it is observed that there are only two points in a revolution of the crank at which the connecting-rod (*supposed here to be infinitely long,*) forms with it a right angle, and it is only at these points of full-leverage that the whole force of the steam transmitted through the rod is acting to produce effective motion of the crank. These positions are denoted by figs. 1 and 2. But, again, in the positions indicated by figs. 3 and 4, the connecting-rod and crank are in the same straight line—technically called the "position on the centre," or passing the "line of centres," and by some writers termed the "dead-power points"—in which the leverage of the crank is nothing, and, consequently, no power, however great, acting through the rod, could produce rotatory motion in it in either direction. The force at these two positions is exerted upon the crank-centre alone, whilst at the points of greatest leverage, no part of it is thus exerted—the whole there tends to cause the crank to turn upon its centre. At all intermediate

Fig. 1.

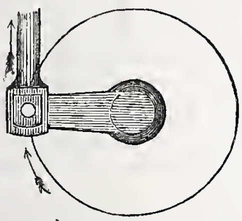


Fig. 2.

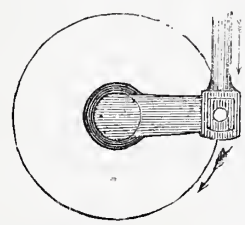


Fig. 3.

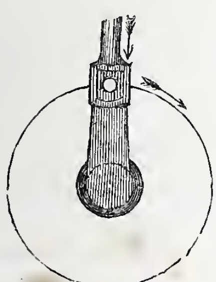
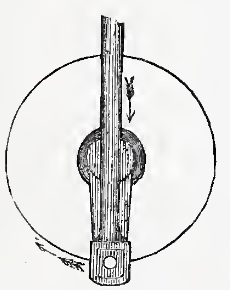


Fig. 4.



positions, the force transmitted through the rod is resolved into two effects—one acting to give the crank revolution, and another acting upon its centre; and it is further clear, that the leverage of the crank increasing from zero to a maximum during the first quarter revolution, and diminishing from a maximum to zero during the next quarter, the efficiency of any force transferred to it through the connecting-rod, will in like manner increase from zero to a maximum, and diminish from a maximum to zero.

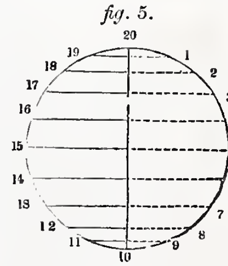
Were we, therefore, to stop short in our examination at this point, we might also conclude that the crank is a "losing lever," and set about equalizing this *apparently* most unequal action, and saving the power so prodigally thrown away in our steam-engines. Another step in the analysis serves, however, to convince us, that the pressure produced upon the crank-centre does not imply a loss of dynamical force; that when the apparent loss is greatest, there is no loss whatever, and that at every point the effect produced is in direct relation to the quantity of steam producing it.

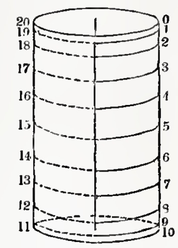
To show how these conclusions are arrived at, let it be recollected, that at the two extremes of the line of centres—the neutral points—the greatest apparent loss takes place. A moment's reflection is, however, sufficient to convince us that, at these instants, there cannot possibly be any loss; there is no power expended, and consequently none wasted. The supply of steam, the element of power, is closed—the communication with the boiler is cut off—the steam in the cylinder has done its work, and only waits to be dismissed the instant the eductive passage is thrown open for egress. Communication being opened with the boiler, the entering steam finds the piston almost in contact with the end of the cylinder at which it enters; it insinuates itself into the vacant disc—the piston yields to the pressure, and begins to move towards the opposite end of the cylinder. At first its progress is slow, but gradually accelerates, till, on reaching the middle of the cylinder, it moves with the full velocity of the crank in its circle. But from the moment that it passes that point, that is, half-way to the end of its course, the velocity of the piston begins to be retarded, and its final stoppage prepared for. At last the rectilineal motion, having dwindled to nothing by insensible shades, altogether ceases. The expenditure of steam, meantime, corresponds to the motion of the piston: first, it expands with a continually increasing movement to the point of half-stroke, and then its expansion begins to diminish, till, finally, it ceases to produce any effect, and is released from its confinement by the opening of the eductive port.

Such is the history of the progress of the piston from one end of its cylinder to the other. During the first half of its course its motion is gradually accelerated by increasing increments; it then begins to be retarded, and is finally brought to rest by decrements of motion in the inverse order.

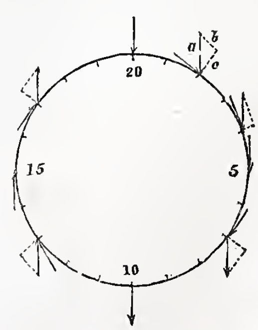
Our next business is to trace the simultaneous motion of the point which, by its connexion with the piston, is carried round the circumference of a circle, while its mover progresses in its reciprocal strokes in the cylinder, and to inquire how this gradual change from rest to motion, and from motion to rest, can be rendered consistent with the uniform motion of the crank in its circle. To facilitate this part of the inquiry, and show the relation which these motions bear to each other, it is necessary to have recourse to a simple diagram such as that annexed, in which the circle represents the path of the crank, and the figure below it, the steam cylinder of corresponding length. The numerals on both figures represent the places of the crank and piston at given instants of time. The motion of the crank is supposed to be uniform, and therefore its orbit is supposed to be divided into twenty equal parts, the first ten numerals being placed on the descending, and the other ten on the ascending, side of the circle. The length of the stroke of the piston—which is equal to the diameter of the circle—is similarly divided into ten unequal parts, showing the places of the piston at those instants of its stroke which correspond with the contemporaneous points of the crank's orbit—the first ten numerals corresponding both in the circle and cylinder with corresponding points of reciprocation and revolution.

fig. 5.





Now, in order to arrive at a proper estimate of the relation which exists between the pressure of the steam on the piston, and the quantity of effect produced in revolving the crank, and that part of the pressure of the steam which produces no motion, and which is therefore said to be lost,—let us construct such a diagram as that annexed of the crank's orbit; and let the arrows placed vertically denote the force of the steam transferred through the connecting-rod—those placed as tangents, the part of that force tending to produce revolution in the crank, and the lines directed to the centre, the apparent loss. Then knowing the amount of steam pressure transferred, we can easily ascertain the relations of the lines *a*, *b*, and *c*, to one another, and thereby the force acting in the direction of the circle, and also that acting upon the centre of the crank at those



points. Other figures, showing the relations of the forces, may in like manner be constructed at any of the other given points of the circle—the conditions of the construction being simply, that a represent in magnitude and direction the force transferred through the connecting-rod, that b be parallel to the direction of the circumference (or tangent) of the circle at that point, and that c be directed from the same point to the centre; and further, that b and c be produced till they meet, and thus determine each other's magnitude in relation to the constant quantity, a. Constructed upon a sufficiently large scale, the relation of the forces may be ascertained with sufficient accuracy by the compasses; and only a very slight knowledge of calculation is necessary to verify the results contained in the following table, which is calculated for all the points marked in fig. 5, upon the assumption that the force of the steam a = 100 lbs.

Points in fig 5.	Arc moved over by the Crank.	Force in the Direction of Revolution: Value of b.	Pressure upon the Centre: Value of c.	Relative Velocity of Crank to Piston
20	0°	0·00	100·00	Infinite.
1 and 19	18°	30·90	69·10	3·236
2 " 18	36°	58·78	41·22	1·701
3 " 17	54°	80·90	19·10	1·236
4 " 16	72°	95·11	4·89	1·051
5 " 15	90°	100·00	0·00	1·000
6 " 14	108°	95·11	4·89	1·051
7 " 13	126°	80·90	19·10	1·236
8 " 12	144°	58·78	41·22	1·701
9 " 11	162°	30·90	69·10	3·236
10	180°	Mean. 63·138	Mean. 36·862	Infinite.

According to this table, then, only about 63 per cent. of the steam force transferred through the connecting-rod to the crank tends to produce revolution of the crank round its centre, while 37 per cent. of the force tends to produce motion in the direction of the centre. Now, it is this 37 per cent. (something more than one-third of the whole force) which is considered to be lost by the crank; and the reasoning which has led to that conclusion is in every way similar to that here adopted. But, without proceeding further, it might be suggested, that as the centre of the crank is fixed, and prevented from yielding, except to the force acting to produce revolution, that no *power* can possibly be expended in this pressure; for no motion is produced towards the centre, but only in the direction of the circumference. That which we call *power* is not pressure, but pressure combined with motion. The ram of the pile-driving engine may be suspended by the shears for any length of time, without expenditure of force —it becomes no lighter by suspension, and not a whit less ready to fall, in obedience to the force of gravity, when it is released. Yet, if mere pressure be taken as power, that power ought constantly to become less and less by continuance of action; and not only the ram, but every body which presses upon the earth's surface, ought, according to this doctrine, to be giving out their *power;* and applying the supposition to the case in hand, there must be an enormous waste of *power* constantly incurred in the steam engine, by the pressure of the steam upon the interior of the boiler in which it is generated.

It is to such absurdities as these that we are led by confounding pressure and power. We must therefore bear in mind that, in all calculations respecting power, we must attend to the space passed over, as well as the force exerted in that space; and that a force of 1 lb., moving through ten inches, is equivalent in effect, as already stated, to a force of 10 lbs. moving through a space of one inch: that is, in calculating the quantity of effective power, a greater velocity is equivalent to a greater force. Applying this to the case in hand, let the connecting-rod and crank be so nearly in a line, that a pressure of 100 lbs. upon the piston exerts only a pressure of 1 lb. in the direction of rotation; then does it follow, that if the piston advance minutely in the cylinder, the extremity of the crank will advance one hundred times as far along its path. The quantity of effective power developed is thus equal to the power expended; for the quantity of motion generated in the machine is precisely what is due to a pressure of 1 lb. acting through and hundred times the advance of the piston—or, what is the same thing, to the pressure of 100 lbs. acting through that advance itself. This is true of any other minute motion of the piston, and may be verified as nearly as the approximate results contained in the table given above will allow, for any part of the crank's revolution. Thus, by reference to the table, it will be observed that when the crank has advanced 18° in its orbit, the force of the connecting-rod, tending to produce revolution of the crank, is 30·9 lbs., and that the relative velocity of the crank is to that of the piston as 3·236 to 1. Now, supposing these relations to remain the same while the piston advances through one inch, then the pressure being 100 lbs., the effective power of the piston is expressed by 100 lb. × 1 = 100 lb.; and the pressure in the direction of the crank's orbit being 30·9 lbs., and the velocity 3·236 inches, the effective power is expressed by 30·9 lbs. × 3·236 = 99·99 lbs.—that is, 100 lbs. very nearly, the deficiency arising from the fractions of the factors 30·9 and 3.236 not being complete.

What is thus true of a minute portion of the stroke holds equally true of it as a whole; for while the piston moves through the length of the cylinder, which is equal to the diameter of the crank circle, it moves the crank through one-half of a revolution. Now, the length of the diameter of a circle bears to the length of its semicircumference the following relation—

Diameter : semicircumference : : 2 : 3·14159,

that is very nearly the ratio 63 : 100. In other words, if the length of the stroke be 63 inches, the space passed over by the crank in its orbit will be 100 inches. Now, the mean force on the crank, in the direction of revolution, is shown by the preceding table to be also 63 to 100, which shows that the mean force in the piston is greater than the mean force in the crank in precisely the same ratio, in which its velocity is less than the velocity of the crank. And, therefore, the effective power in the one is equal to the effective power in the other. To render this, if possible, more clear—the pressures on the piston and crank being inversely as the spaces through which they move, and the motive force in the cylinder being 100 lbs., moved through a space of 63 inches, (the length of the stroke,) we have as the effective power of the piston 100 lbs. × 63 = 6300 lbs.; and for the motive power given out in the crank 63 lbs., moved through a half revolution of 100 inches, that is 63 lbs. × 100 = 6300 lbs.

The conclusion then that the power of steam is by no means disadvantageously applied through the crank in the ordinary way, rests upon these facts:—1. The velocity of the crank in its circle is in the inverse ratio of the pressure upon it. 2. The mean pressure on the crank during the whole revolution is less than the pressure on the piston in exactly the same proportion that the space moved over by the latter is less than the space described by the former, so that the whole effect is equal to the whole power. 3. The steam is not at all expended at the neutral points, and its expenditure at every other point is exactly proportioned to the pressure it gives out in useful effect. 4. The velocity of the piston is the ratio of the force acting at each instant on the crank to produce revolution. Making, therefore, allowance for friction, we may rest satisfied that we receive through the crank in actual work done all the power of the steam applied to it in the cylinder—and that no force whatever is lost by obliquity action.

This is, indeed, proved in the most satisfactory manner by the practical fact, that the crank-engines of Cornwall are in every respect as effective, and do as much work as the average of those which have no crank. And it may be worthy of remark, that as far back as 1837 it was proved in the most careful way by Mr Smith of Manchester, that the work done by the crank-engines of Charleston and Wheal Kitty, constructed by Mr Sims, was within ten per cent. of the power employed—a fact which of itself would seem enough to induce contrivers of crank substitutes to reconsider the question.

As a means of converting the reciprocation of the piston of a steam-engine into continuous revolving movement, the crank possesses some singular and beautiful properties which distinguish it from every other mode of producing that conversion, and which appear to be so perfectly adapted to the nature of steam and the constitution of solid matter that we are indebted to it materially, although indirectly, for the very great advantages we derive from the modern steam-engine as a source of mechanical power. Ingenuity has been taxed to the utmost to find substitutes for it, which should remedy its imaginary defects; but after many vain efforts, it is found that the crank is the magic rod through which the mighty force of the element can be transmitted peaceful and docile. It may be said, that successful

JOHNSTONE'S LOCOMOTIVE BOILER

Fig 3

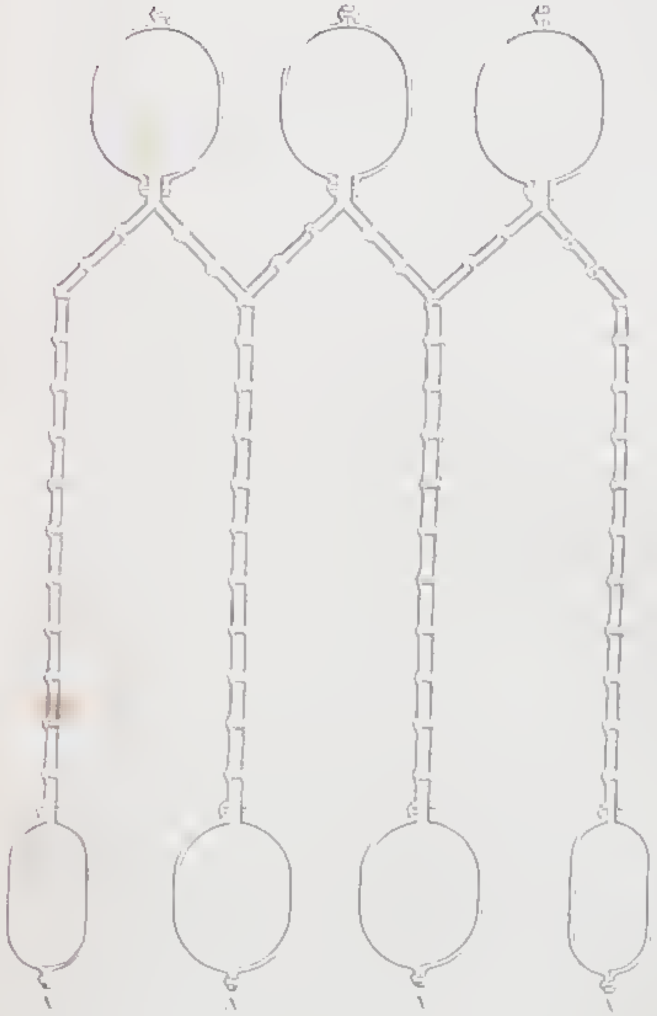


Fig 2

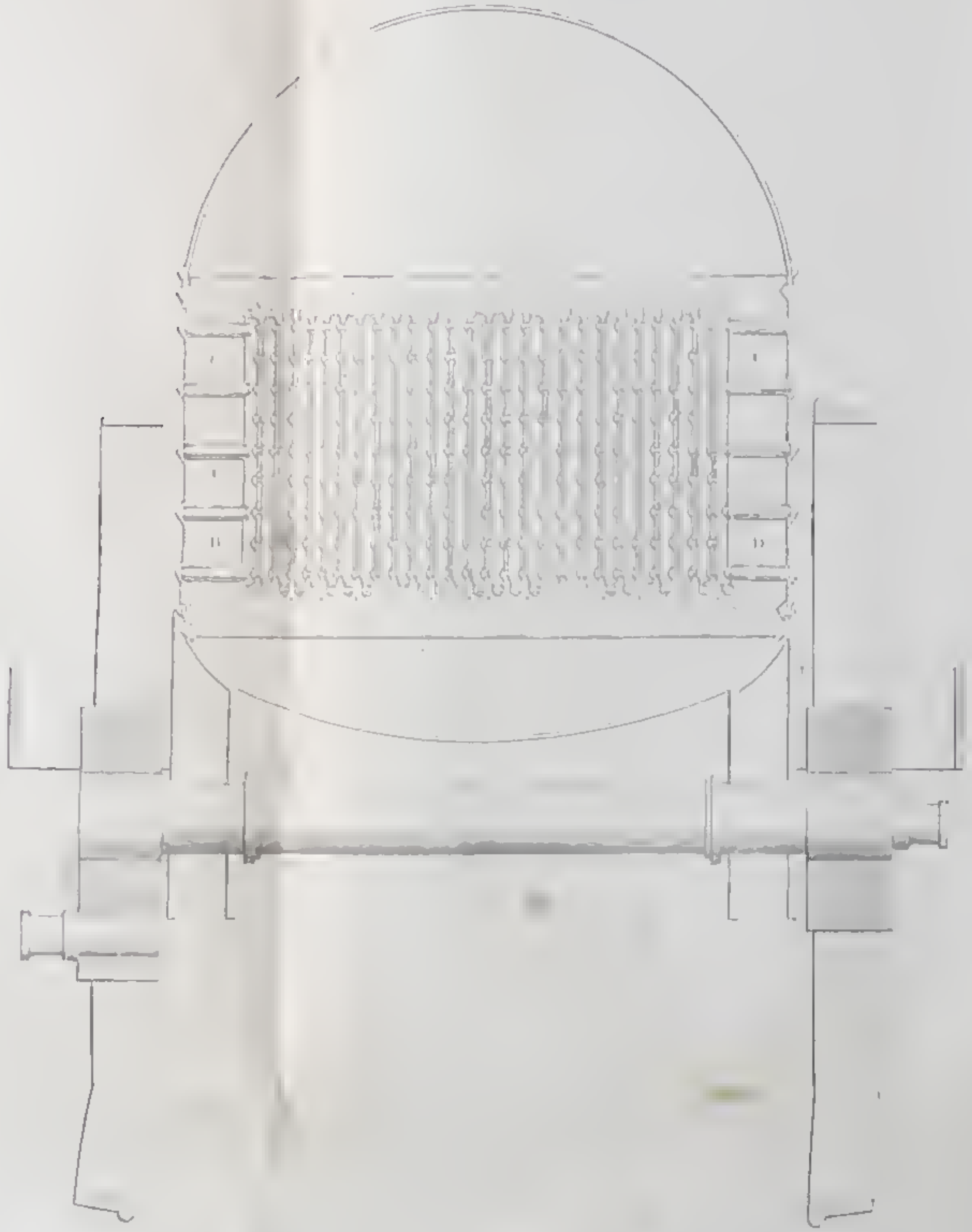


Fig 1

substitutes have been contrived, and the beautiful sun and planet motion of Watt may be cited in evidence; but only a very slight examination of the contrivance is necessary to show that the crank, though disguised, was present, and that the success depended upon its presence. It was not a want of confidence in the crank which produced the sun and planet motion: it owed its contrivance simply to an invidious patent, and as soon as that patent expired, the disguise disappeared, and the simple unincumbered crank assumed its place.

To see in what its superiority consists, let it be observed that, in the reciprocating piston the following things take place: the piston is to be put in motion in one direction, then stopped; then put in motion in the opposite direction, stopped again; motion in the first direction begun, and once more made to cease. But these processes which produce the change of state from rest to motion, and from motion to rest, require time. Matter in motion acquires momentum, which must be gradually removed, otherwise these moving parts are subjected to concussion, as by the stroke of a hammer, and either suffers or produces injury. On the other hand, when brought to rest, matter cannot be instantly set in motion in the opposite direction without a stroke and concussion equally violent. These effects, therefore, cannot be instantaneous; yet it is necessary that the motion which the steam gives off, should be converted into continuous and uniform motion, while the parts of the engine itself must be allowed time to be brought to rest without shock, concussion, or jolt, and gradually and gently be again urged to their greatest velocity in the opposite direction. All this the crank effects with the utmost nicety of adjustment: it stops the piston as gently and softly as if a cushion of eider-down were placed to receive it; and after having brought it to rest, as gradually begins and accelerates its motion to its highest velocity in the opposite direction. An adjustment so complete is only possible in such a relation as that which subsists between the crank and the piston: the one describing uniformly the circumference of a circle, while the other moves by simultaneous graduations of alternately increasing and diminishing extent.

Now, comparing this mode of action with that of any of the substitutes for the crank, by which it has been proposed to gain uniformity of power, we shall find that in these it would be required that the transitions from rest to motion, and from motion to rest, should be instantaneous, and hence such arrangements being soon disordered, have been speedily abandoned.

Perhaps one of the highest recommendations of a piece of mechanism is, that any very slight error in its construction shall not very materially affect its usefulness, nor any very slight derangement of its adjustment be attended with immediate deterioration; but that, on the other hand, the efficiency of the machine shall be consistent with such degrees of correctness of workmanship as can easily be accomplished, and such attention in superintendence as can readily be obtained; also, that the progress of disrepair shall be so gradual as to give timely warning of danger, and admit of ready repair and readjustment. The crank is precisely such a piece of mechanism; it possesses the property of reducing the errors of construction, arrangement, management, and adjustment, in a remarkable degree. This is well shown in respect to the valves. It is at the top and bottom of the stroke that the opening and shutting of these take place, and it is at these points that a minimum of the pressure on the piston is transferred to the crank, so that if the valves do not open with perfect precision, but either a little too late, or too soon, then will such error at that part of the circuit be comparatively harmless, for just then the motion of the piston is so slight that, through an arc of twenty degrees of the crank's orbit, it does not advance the hundredth part of the stroke, and therefore the effect of any error contained within that range will not affect the result of the crank by one-hundredth part of its full amount. Any error of adjustment is therefore diminished in effect to one hundredth part of what would be produced, were the motion of the piston to be uniform, in portions corresponding to the arcs described, as would be the case in any other species of rotatory conversion.

To this enumeration we might add other properties, but, perhaps enough has been said to remove the fallacy which would convert the simple crank into a destroyer of power. If so, our object is attained, and we shall be glad to find that the ingenuity and perseverance hitherto expended upon substitutes for the crank, are directed to more useful and rational purposes. A sufficiently wide field is open to improvement in the mechanical arts without interfering with a mechanism, which, we have no hesitation in saying, is as perfect and simple in its nature as human ingenuity can make it.

In conclusion, we have to state, that we claim no merit for the exposition embraced in this paper: the main part of it is borrowed, with only slight modification, from Mr. J. S. Russell's excellent paper "On the Fallacies of the Rotatory Engine," published in the *Transactions of the Royal Scottish Society of Arts*, and republished, with some alteration, in his work on the steam-engine. We have also made some use of an essay by Mr. Edward Sang, "On some Misconceptions concerning the Actions of Machines," published in the same Transactions; and of some unpublished documents on the "crank question."

In Article II. on this subject, we shall add a descriptive history of the substitutes which have been proposed for the crank, from that of Jonathan Hulls to the present time, and we shall take care that the curious list may be as complete as possible.

JOHNSTONE'S LOCOMOTIVE BOILERS.

Illustrated by two Plates.

These boilers possess some peculiar properties which we think are worthy of careful examination; the enormous amount of capital now invested in locomotives renders improvement in them a matter of great importance; the coke account in railways is the principal one of their annual expenditure, and of the large sums spent by railway companies on the repair of locomotives, the principal item is for tubes and fire boxes. A remedy for these evils is most likely to be found by enquiring what are the means employed to obtain the greatest useful effect from the heat produced by the coke.

The large amount of steam required for locomotives and the small quantity of space which can be devoted for their boilers, obliges engineers to compress a great amount of heating surface in boilers of small dimensions. The most advantageous arrangement of that heating surface in these boilers is a problem still to be solved.

The common plan of locomotive boiler is an admirable arrangement of heating surface, if the end to be accomplished were the keeping hot of some fluid such as melted lead which is not converted into a gaseous body, for in that case also the surface of the tubes would be effective heating surface, because there would be no gaseous body rising from the midst of the melted lead, and preventing its being always in contact with the tubes; but as a machine which is to be employed for the purpose of converting a liquid into a gaseous body by heat transmitted through metal, it is one of the worst arrangements that could be devised.

According to Mr. G. P. Bidder's evidence before the Guage Commissioners on the experiments made to ascertain the amount of evaporation by narrow guage locomotives, he stated that 178 cubic feet per hour was the amount of water consumed by one of those engines. According to De Pambour's experiments, one fourth of the water consumed by a locomotive, goes into the cylinders in a liquid state; after making that allowance, we have 134 cubic feet of water actually converted into steam per hour. If 50 lbs. be considered the pressure of the steam in the boiler, each cubic foot of water evaporated will produce 440 cubic feet of steam, making 58,960 cubic feet the total steam produced by the boiler per hour. What quantity of this steam was produced by the heating surface on the tubes? This will be ascertained by reference to the proportions of heating surface in the tubular and furnace parts of these boilers —500 square feet on the tubes, and 50 square feet on the fire-box are the proportions of heating surface of the majority of the narrow guage locomotives, but, according to Mr. Stephenson's experiments one square foot of heating surface on the fire-box produces as much steam as three on the tubes; if this allowance be

made, then 45,250 cubic feet is the amount of steam produced per hour, or 754 cubic feet per minute by the tube heating surface.

Now, in a locomotive containing the amount of surface above referred to, and having three quarter inch water spaces between the tubes; the area of the spaces between the tubes taken in a horizontal line at the row of tubes at the greatest breadth of the boiler will be found to be eight and a half square feet. If the 704 cubic feet of steam produced per minute from the tube surface be divided by $8\frac{1}{2}$, the number of square feet of area through which that steam has to pass, we have 88 cubic feet of steam as the quantity that has to pass through every square foot of area of the spaces between the tubes measured in a horizontal line at the greatest width of the boiler. This quantity is still better impressed on the mind when stated in inches, viz., 1056 cubic inches of steam pass per minute through every square inch of area of the space between the tubes of a locomotive.

Having given the facts of the case, we shall now examine the results which must flow from them.

As the tubes of a locomotive are not placed immediately over each other, but zig-zag, the steam ascending among them must come in contact not only with the lower parts of them, but also with the sides and part of the top. Now, it being borne in mind that the space between those tubes is only three quarters of an inch wide, that it is filled with a liquid, and 1056 cubic inches of a gaseous body has to ascend per minute up through every square inch of area that is between those tubes. Is it within the range of possibility for that liquid to remain in contact with the tubes under these circumstances? It is not!—and this is the source to which may be traced all the evils attending the common plan of locomotive boilers.

First—The tubes are injured because they are over-heated for short intervals of time; whilst the steam is in contact with them.

Second—The extravagant consumption of fuel arises from a large proportion of the heating surface (fully one-half) being ineffective, owing to the steam, a non-conductor of heat being in contact with it.

Third—The fact made known by De Pambour that one-fourth of the water consumed by a locomotive is carried in a liquid state by the steam into the cylinders is no longer a matter of astonishment when we consider the rate at which the gaseous body, the steam, ascends through the water in the narrow spaces. The loss of fuel from the hot water carried into the cylinders is enormous.

The preceeding statement shows that the improvements yet to be made in locomotives are, first;—An arrangement of heating surface, so that the steam, the instant it is formed, shall be detached from the heating surface, and carried off in such a way as not to be again forced into contact with other portions of the heating surface of the boiler. Second—The boiler should be constructed either so that no water will be thrown up with the steam, or else there should be an arrangement made for the water raised by the steam, being separated from it, and retained in the boiler, instead of allowing it to pass into the cylinders. The improvement in this arrangement of the heating surface shall be referred to hereafter.

As to the construction of a boiler, so that no water will be thrown up with the steam, this can only be accomplished by making the water spaces very wide, an alternative which cannot be adopted in a locomotive boiler; and as in all narrow water space boilers a large proportion of the water is thrown out of the spaces, and wet steam produced; we must, therefore, resort to the alternative of constructing boilers so that the water thrown up by the steam shall not be carried into the cylinders.

The question may be asked, how does it happen that the water thrown up with the steam passes with it into the cylinders of locomotives, whilst there is a large steam chamber provided, in which the water might separate from the steam, and fall back into the part of the boiler allotted for water? The enormous amount of steam rushing up constantly from the narrow water spaces between the tubes, and at the sides of the furnace, must be kept in view, and also the fact that every part of the water level or surface of the water in a locomotive boiler is giving forth steam: there is not a single square inch of the surface of the water in one of those boilers which can be pointed out as not giving forth steam; this being the case, how is it possible for the water thrown up by the steam to get down again into the body of the water, seeing that there is no cessation of the production of steam, and that the whole base or resting place of the accumulated steam is vomiting forth unremittingly, fresh supplies of steam and water combined. It is contrary to the nature of things to expect a locomotive boiler to give dry steam, because there is no provision made for the water to separate from the steam. In order to allow the water to separate from the steam, some portion of the water surface of the boiler should be provided that would not be required to emit steam, and care should be taken in the construction of the boiler that the water after it has separated, and settled down from the steam, shall be in free and uninterrupted communication with the mass of water in the boiler. Engineers will reply that this they cannot do—as it would either deprive them of some portion of the space already allotted for useful purposes in the boilers, or else they will have to increase the size of the boilers, which it is not in their power to do. Mr Johnstone's plan of arranging the heating surface of boilers provides a remedy for that. The existing arrangement of tubes in locomotive boilers is a bad one for economising space in heating surface; a great deal now can be obtained in a given space by constructing the heating surface of flat flues with perpendicular water spaces between them, as exhibited in fig. 2, plate II. This arrangement enables so much to be obtained in a small space that a portion of the room usually allotted in narrow guage locomotive boilers can be converted into a space for allowing the water to separate from the steam, and return into the body of the boiler. C D, C D, fig. 3, are the water spaces allotted for that purpose; they extend from the top to the bottom of the boiler, in order to let the water thrown up, return down, and re-enter the narrow water spaces as indicated by the arrows in the drawing. In the plan referred to, the cross sectional area of the two side, or descending water spaces C D, C D, is rather larger than the cross sectional area of all the water spaces between the flues, and around the furnace, the reasons for making the water spaces of these proportions are as follows:—As the water in the two side descending water spaces C D, is not liable to be converted into steam, as no heat is allowed to act on these spaces, the half flue next them being closed up, therefore, the water in these spaces is 440 times heavier than any steam that is produced in the ascending water spaces between the flues, or around the furnaces, if the pressure on the boiler be supposed to be 50 lbs. on the square inch, consequently, no steam can remain in the narrow spaces between the flues, as the superior weight of the water in the descending water spaces C D, is sure to cause it to rush down and dislodge the steam from the narrow ascending water spaces. As to the area of the descending water spaces, if nothing but steam came out of the ascending water spaces, they might be of less area, but as we know that the whole contents, both steam and water, of the ascending water spaces are set in motion, both water and steam being thrown out of them, it is necessary that the area of the descending water spaces should be such as at all times to enable them to yield, or allow such a mass of water to descend as would at once fill or replace the contents of all the ascending water spaces. This arrangement of water spaces produces such a current of water throughout a boiler that no over-heating of the metal can occur, as no accumulation of

steam can take place on the heating surface. The furnaces are made so that water circulates up the sides, and over the roof of them the same way as in the other parts of the boiler.

The next advantage we have to point out, which this plan of boiler possesses, is the large amount of area for draught through the flue. In the common narrow guage locomotive boilers of the amount of heating surface, such as that to which we have already referred, the total area of draught-way through the flues of the tubes is $1\frac{3}{4}$ square feet, whereas the boiler of which we have given drawings, has $3\frac{2}{3}$ square feet of area for draught through the flues —this is a very great advantage, being more than two to one in favour of the boiler we are now describing. This advantage operates in two ways—First, the destruction of tubes chiefly arises from the mechanical effects of particles of coke carried through them in consequence of the great velocity of the draught. Now, in Mr Johnstone's plan of boiler a given amount of air can be drawn through the flues in a given time, at less than half the velocity required to draw the same amount of air in the same time through the tubes of a common locomotive boiler. That result arises wholly from the increased area for draught through the flues, but the chances of deterioration in Mr Johnstone's plan of flues is still further reduced owing to their shape, each flue measures 21 inches from top to bottom, and 1 inch wide—whereas the tubes in a locomotive are $1\frac{1}{2}$ inch diameter—tubes are the very best shape of flue that could be adopted, in order to get the full benefit of the destructive properties consequent on the transmission of irregular pieces of coke through them. Between the projectile force of the pieces of coke and their tendency to gravitate to the lower side of the tube, it is clear that the irregular shaped pieces of coke must be continually striking the bottom, and rebounding from it to the top and sides, whereas, in the flues shown in the accompanying drawing, there is such a distance between the top and bottom of them, that there is not the same chance of the pieces of coke striking so frequently upon the metal of these flues as it does in the tubes. Second, The more than doubled area for draught, given by this plan of boiler, enables the velocity of the draught to be diminished one-half, and, consequently, the steam blast may be reduced a half, this will effect a very great saving in the power of locomotives.

The following is a comparative statement of the proportions of the boiler of which we have given plans, and one of the improved outside cylinder locomotives on the Grand Junction Line. The first column is the particulars of the old plan of locomotive boiler —the second is that of the improved one:—

	Square Feet.	Square Feet.
Boiler-heating surface, ...	$497\frac{1}{2}$	700
Furnace ditto, ...	$48\frac{3}{4}$	126
Total heating surface in boiler,......	$546\frac{1}{4}$	826
Area of fire-grate, ...	$9\frac{1}{3}$	18
Area of flue passage for draught, ...	$1\frac{3}{4}$	$3\frac{2}{3}$

The tubular locomotive referred to, has 139 tubes of $1\frac{13}{16}$ inches external diameter, and $1\frac{1}{2}$ inch diameter within the ferrules, the water spaces between the tubes are three-quarters of an inch wide. We are prepared for some of our engineering friends asserting that they now possess locomotive boilers on the narrow guage lines which contain much more heating surface and a greater flue area than the tubular locomotive above referred to. The demand for powerful locomotives, consequent upon the struggle between the broad and narrow guages has brought into existence those locomotives with increased amounts of heating surface and flue area. But by what means has their increased proportions been obtained? Has it been by increasing the external bulk of narrow guage boilers? If so, all is right—and if the external bulk of common boilers has been increased, then this new plan of boiler can also be enlarged in its dimensions. But if the increased amount of heating surface and flue area has been obtained by stuffing a great number of tubes into locomotive boilers of the common dimensions, the water spaces between the tubes and around the furnace must have been diminished in width, and injurious consequences will result therefrom. This mode of attempting to increase the power of locomotives reminds us of the well-known fact, that some birds, when frightened and pursued by an enemy, thrust their heads into any hole, imagining that they are safe when they no longer see the danger—so engineers, because they cannot see the evil arising from the diminished water spaces consequent upon their thrusting an increased number of tubes into boilers, they think all is right—they say one width of water space is just as good as another, there is water in contact with all parts of the heating surface when the boiler is first filled up, and after the fire is applied and steam given off, there is more water forced in to keep the boiler supplied, the water in the glass guage is at the same height as when the fire was lighted, and of course there must still be water in contact with all parts of the heating surface. So think those engineers; like the birds, they consider there is no danger, because they do not see it. The experiments that have been made on the spherical condition of water, and other facts on boiler explosions daily coming to light, convince us that there are circumstances connected with the explosion of boilers which are only to be guarded against by attention to the dimensions and arrangement of the water spaces, and to the intensity of the heat applied to them.

In plate I. we have given a side elevation of a locomotive, fitted with Mr Johnstone's plan of boiler. The body of the furnace is 8 feet long, the furnaces are 6 feet long and three in number. Fig. 1 gives an end view of them, and Fig. 3 is a cross section of them. It is the peculiar mode of fastening the inner and outer roofs of the furnaces together which enables them to be made of such length without fear of the roofs giving way. In Figs. 1 and 3, A, are the water conductors at the bottom of the furnaces which supply the spaces at the sides and between the furnaces with water. B, B, are the steam conductors of the furnaces. They convey into the body of the boiler the steam produced around the furnaces and the water thrown up with that steam. Fig. 2 is a cross section through the body of the boiler. C, D, C, D, are the spaces through which the water thrown up by the steam descends to the bottom of the boiler.

The furnaces are made of greater length than usual in order that a great amount of heat may be obtained without that intense action of the fire, which is unavoidable, if a large amount of heat be required for a small fire-place; perhaps this has been carried too far; we think the furnaces, as drawn, too long; if they were made a foot shorter, and that length added to the body of the boiler the furnaces would be more manageable; we are also of opinion that two furnaces would be better, the construction would be simpler. These changes would diminish the heating surface in the furnaces, but the increased length of the body of the boiler, would give on the whole an increase of heating surface of 56 square feet, making the total heating surface of the boiler 882 square feet.

It will be observed, that the funnel does not rise up close to the boiler, as is usual, the extra width of smoke-box is made in order to give greater justice to the hanging damper or partition which is placed in the smoke-boxes of some locomotives to throw down the sparks and obtain the greatest effect from the heat without obstructing the draught. Interruption to the blast from these dampers arises only when they are placed too close to the tube ends, and an insufficient area of space left for the products of combustion to pass under them.

NATURAL PHILOSOPHY AND CHEMISTRY.

CHAPTER XXII.

ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

Part II.—Electro-Magnetism.

1. In none of the modern sciences have important discoveries more rapidly accumulated than in that of which we are now about to treat. When we call to mind the first faint glimmering, in 1774, of that light which shines so brightly in 1852; when we recur to the essays of Van Swinden in the former period, and peruse in those essays the arguments of that professor against, and those of Hubner and others, for, the identity of electricity and the magnetic force; thence passing on to the investigations of Beccaria, in 1777, and to those of Ritter, at a later period, until, after a long interval, we reach the grand discovery of Oersted,—we can scarcely conceal our wonder, that the many brilliant thoughts and striking facts contained in the writings of those distinguished men were not sooner seized upon by the mighty minds that shed such a flood of scientific light upon the dawn of the nineteenth century. But this wonder at the tardiness of the electro-magnetic march, until the scattered facts fell into order, and produced a science in the hands of Oersted, is turned into admiration, when we consider the multitudinous array of experiments and observations since contributed from all parts of the world, and the surprising industry which has built up so many beautiful theories, and brought the infant science of 1820 within the dominion of strict mathematical demonstration in the brief period of a quarter of a century.

2. But while we acknowledge the state of perfection which the science has attained at the present time, it must be confessed, that we are very far, indeed, from that degree of knowledge on the subject which would enable us satisfactorily to explain the mode of production of the various extraordinary phenomena of electro-magnetism which we daily witness. It is true that we can measure forces, calculate intensities, and predicate effects with astonishing accuracy; but when we attempt to reason upon these effects, and to apply the knowledge we have acquired to the obtainment of more important results, we find ourselves disappointed by various anomalous circumstances, and are cast back upon our original knowledge, there to take our stand, while we prepare to attain our object by a surer path, and more efficacious method.

It is believed, that many of the difficulties which thus beset our onward progress at every turn, may be removed by bringing before the reader, in as clear a light as possible, a general view of the present state of our knowledge of electro-magnetism. We do not, of course, presume to imagine that we can, within prescribed limits, bring forward every fact, and every experiment; our object will rather be to draw the reader's attention to those principles of the science which are generally recognised as established, and to give such illustrations of them, and arrange them in such a form as shall induce the experimentalist to turn his investigations into the proper channel, and avoid those shoals towards which so many have been previously attracted by false calculations.

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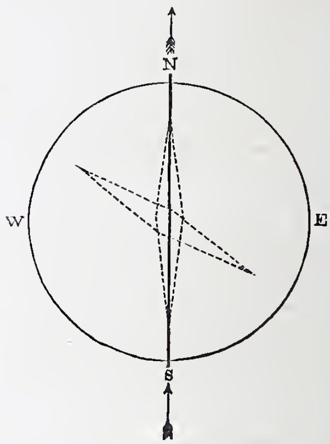
3. Electro-magnetism, in its special and particular sense, may be defined to be that peculiar property or power which a current of electricity, passing along any conducting substance which is carried round a piece of soft iron—previously unmagnetised—in a spiral direction, bestows upon that piece of iron, of attracting towards it, pieces of a similar metal when presented to it—thus constituting the soft iron, so long as the current is passing around it, a magnet, similar in all respects, to a natural magnet; and the iron attracted by it, another magnet by induction.

4. But, in its general sense, electro-magnetism signifies that power which electricity exerts upon magnetised or unmagnetised steel or iron, causing motion therein; and, in the case of the magnet, neutralizing or reversing its terrestrial polarity.

5. The experiment which led to the discovery of electro-magnetism was conducted by Oersted in the following manner:—He took a magnetic needle, balanced on a pivot, as in the mariner's compass, and, permitting it to arrange itself naturally in the magnetic meridian, he placed a copper wire, uniting the positive and negative plates of a simple voltaic battery, in a horizontal position above the needle, and parallel to it. This being done, the needle instantly moved from its previous position, and assumed a new position to the east or west of north, according to the direction of the electric current along the copper wire. This experiment led to the first general law, "that the end of a magnetic needle, which is nearest that plate of the battery towards which the current is flowing, immediately moves to the westward, or to the left hand of a spectator facing the direction in which the current is moving."

6. For instance, let the circle N, E, S, W, represent the card of the mariner's compass in its horizontal position. Suppose S, N, extending beyond the circumference, to represent the horizontal wire connecting the two ends of the battery, and the compass needle to lie immediately under and parallel to it, both having a northerly direction. If the battery be now put in action, with its negative plate in connexion with that end of the wire marked N, the current will move in the direction of the arrows, and that end of the needle, pointing north, will instantly deviate from that position towards the west—the angle of deviation being influenced by the force of the current;—but, now, if that end of the conducting-wire, marked N, be connected with the positive plate of the battery, the direction of the current will consequently be reversed, and, in such case, the end of the needle pointing north will turn towards the east, or right hand of the spectator facing the north.

Fig. 1.



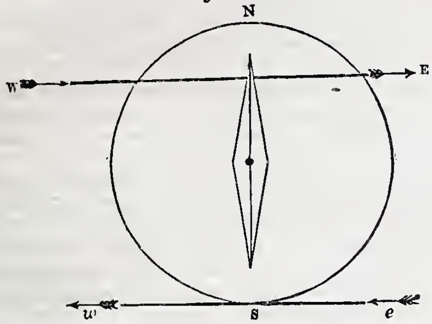
7. Such is the action of the electric force when the conducting-wire is above, and parallel to the needle in the magnetic meridian; but now, if the same wire be placed immediately under the needle—the arrangement in other respects being the same—that end of the needle pointing north, will move to the east, when the current has a northerly direction, and to the west, when the direction of the current is reversed, as in the first example.

8. When the conducting-wire is placed in the same horizontal plane with the needle, or side by side, no easterly or westerly deviation takes place; but when the current flows northerly, that end of the needle pointing north is depressed, or dips when the conducting-wire lies on the west side of the needle, and is elevated when the wire lies on the east. When the direction of the current is southerly, that end of the needle on the west side, which in the former case was depressed, is now elevated, and on the east side, that which was elevated is depressed.

9. If the conducting-wire, instead of occupying any of the foregoing positions, be placed at right angles to the needle, whether above or below it, the needle is undisturbed, unless

the wire be brought very near either extremity; in which case the nearest pole will be elevated when the current moves from west to east, and depressed when it moves in the contrary direction, or from east to west; thus, the pole of the needle pointing north, fig. 2, will be elevated when

Fig. 2.



the current of the wire w, E, enters at w, and passes out at E, but will be depressed when it enters at E, and passes out at w. Similar changes occur, when the wire is placed at right angles to the needle, but beyond its extremities, as represented in the figure by the wire *w, e.*

10. When the conducting-wire, instead of being situated horizontally, is placed vertically, either before the northern or southern extremity of the needle—in such case, if the current move from the under part of the wire towards the upper, the adjacent pole of the needle will move towards the east; but, if the current pass from the upper part of the wire to the under, the deviation of the same pole will be to the west.

11. The above results are not affected by alteration of the conducting metal from a single wire to a number of wires, bound or twisted together, or to a metallic ribbon; neither is the effect altered, except in degree, when different metals are employed. It has been observed, that mercury, when contained in a tube, and applied to the purpose of conduction, exercises a similar influence on the needle; and further, that the interruption of metallic conduction, by interposition of water, does not affect or vary the power, if the interval be not too great. It has also been remarked, that the interposition of metals, wood, resins, stones, or other substances, does not prevent the exercise of the magnetic influence.

12. It follows, that the poles of a magnet, whether it be a permanent magnet of steel, or a temporary one of soft iron—otherwise an electro-magnet—will exert a reciprocal action on a conducting-wire. This fact may be demonstrated by suspending a single and very light voltaic battery by a string, so as to allow of its moving; in which case, if the plates be connected by a tolerably long wire, and the battery be charged, the approximation of the magnet in varying positions will influence the movements of the wire.

13. It appears from the researches of Biot and Savart, that the influence exercised upon the magnetic needle, by the current passing along a conducting wire, diminishes according to their mutual distance; in other words, that the intensity of the action is in the inverse ratio of the square of the distance of the needle from the wire, when considered as applying to a small section of the conducting wire, and is of course proportional to the sine of the angle of deviation of the needle from the wire. But inasmuch as we must consider the length of the current to be indefinite in comparison with the needle, its intensity must be taken to be inversely as the simple distance, when the influence is exerted by a conducting wire of indefinite length.

14. It was the opinion of Oersted—an opinion which has been supported by many eminent men who have since written on the subject—that the influence of the current is exerted on magnetic bodies only, and therefore that needles of brass, or gold, or silver, cannot be affected. But it would be improper to let the supposition get ground, that other metals than iron or nickel, not apparently magnetic, may not be influenced; for the fact is, at least there is the strongest reason for supposing such to be the case, that all metals have similar magnetic relations; but that there is a certain degree of heat peculiar to each, below which it is magnetic like iron or nickel, and above which this property cannot be developed. A magnetic capability, like volatility or fusibility, must be considered to depend upon some peculiar condition of the particles of the substance; and the fact that iron and nickel require temperatures so different for the display of the same property or power, renders it a fair and philosophical conclusion, that all metals possess a magnetic capability—the development of this state depending however upon certain conditions of temperature, and arrangement of the metallic particles. Such a conclusion is certainly far more natural than the opposite one, that iron and nickel are exceptions to a general rule, and have some extraordinary quality altogether different from the qualities of the class to which they belong.

15. An opinion has prevailed, that the heat which expels the magnetic property of iron, influences in some peculiar way its electrical currents, upon which the magnetism has been considered to depend. In like manner a flame and heat of a similar intensity act upon conductors charged with ordinary electricity. The different degrees of heat requisite for iron and nickel present, however, a strong argument against such an opinion.

16. It has been ascertained from inquiries respecting the relation that the temperature which could deprive a magnet of its power over soft iron, bore to that which could deprive iron or steel of its power in relation to a magnet, that when a magnet scarcely reached the boiling point of almond oil, it lost its polarity rather suddenly, and then acted with a magnet as cold soft iron; and that it became requisite to raise it to a full orange heat, before it lost its power as soft iron. It follows, that the power of the steel to retain that condition of its particles which renders it a permanent magnet, yields to heat at a considerably lower temperature than that which is requisite to prevent its particles assuming a similar state by the inductive action of a contiguous magnet. Hence, at one temperature, a permanent state can be retained by the particles of themselves; but at a higher temperature, the same state, although it can be induced by external inductive action, will continue only as long as that action lasts; and at a still higher temperature, all power of assuming this condition either temporarily or otherwise is lost.

17. The foregoing observation will be found to bear upon many interesting facts which will be noticed in the progress of the present treatise, and it is believed will throw light upon certain anomalous effects of electro-magnetic action, which have hitherto eluded satisfactory explanation.

18. It is apparent from what has been already stated, that the magnetising force which derives its origin from the conducting wire, differs altogether in its mode of operation from the other natural forces with which we are acquainted. It does not act in the same direction as that of the current flowing along the conducting wire; neither does it exercise an influence in any plane passing through that direction. It is, on the contrary, clearly exerted in a plane at right angles to the plane of the wire; but notwithstanding it does not attract or repel the magnetic poles in a right line either directly towards, or directly from the conducting wire, as is the case in every other known instance of the exercise of attractive or repulsive influence. Its action is peculiar, in that it produces motion in a circular direction all round the wire; in other words, that the produced motion is in a direction at right angles to a line drawn from the wire to the circumference of a circle bounding a plane which is perpendicular to the conducting wire; that is, it is a tangent to such a circle; it is therefore said that the electro-magnetic force exerts a tangential action.

19. This influence of the conducting-wire on the pole of a magnet is, of necessity, accompanied by an opposite action of the magnet on the wire; for instance, when the current

impels the pole from left to right, the pole impels the wire from right to left, and *vice versâ:* these effects are of course diminished by the influence of terrestrial magnetism upon the needle, which may, however, be obviated, by so disposing a magnet in the vicinity of the needle as to counteract the effect of the earth's magnetism, or by employing an astatic needle.

20. It is a remarkable fact, that, although the conducting wire exercises so marked an influence on the magnetic needle, yet, when a powerful magnet is presented or applied to a conducting-wire connected with a voltaic multiplier, no difference of effect is perceivable,—from which it may be inferred, that magnetic influence cannot retard or accelerate the passage of a voltaic current along a conducting-wire. But a conducting-wire has been found to possess the attractive powers of a magnet, while traversed by the current; for, under such circumstances, iron filings presented to the wire, (no matter of what metal it may be composed), will be powerfully attracted and adhere; but, on cutting off the current, the attractive influence ceases, and the filings drop off. M. Ampere remarked, that when two conducting wires were parallel, and currents flowed through each in the same direction, they attracted one another; but when the currents passed in contrary directions, they were mutually repelled—the repulsive and attractive forces between the two currents being equal.

BOTANY.

CHAPTER V.

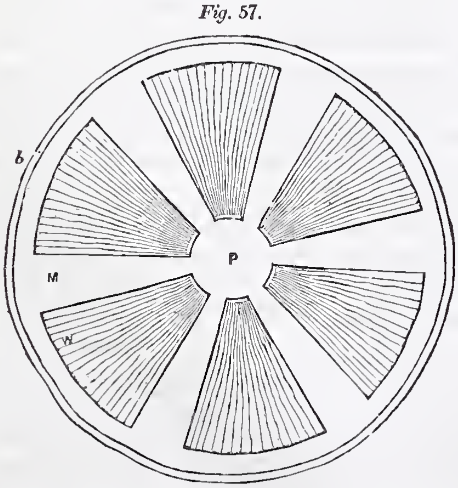
THE STEM—*(continued.)*

Having in the last chapter considered the nature and offices of stems in general, and examined the structure of the more simple, which grow from without inward, and are called *endogenous;* we come now to those which are more complex, which grow from within outward, and are therefore called *exogenous.*

In chapter ii., at page 34, an explanation was given, at considerable length, of the three *tissues* which enter into the formation of plants; namely, cellular tissue, woody tissue, and vascular tissue. To the description of them given there, the reader is requested to look back, in order to refresh his memory, and enable him the better to comprehed what is to follow.

Fig. 57 is a plan of an exogenous stem cut across, pre-

Fig. 57.



senting four distinct sets of parts; P, being the *pith;* *b*, the bark, in two layers, the inner being represented as continuous with the medullary rays M; and W, the wood, consisting of woody fibre and vascular tissue intermingled.

The *pith* was spoken of in last chapter, p. 98, as being a mass of cellular tissue, through which nourishment was sucked up as through a sponge, before the vessels of the plant had become formed, so as to carry on its circulation. It is found in all shoots or branches, and in them is of use; but in older branches, and in stems, its place is now supplied by the vessels which have been formed to carry the juiees up from the gronnd, and it is very generally shrivelled, and shrunk away to nothing. In the Umbelliferous plant, as the Cow-Parsnip, the young shoots are filled with pith, while in the stems it has shrivelled up so as to leave them quite hollow, as every eountry boy knows, cutting them and making squirts of them. Nothing further need be said of it here.

The *bark* is the external covering of the stem, lying immediately over the wood, to which it forms a sort of sheath, and from which it is always distinctly separable. It eonsists of two layers, even on the youngest shoot, the outer being a thin layer of cellular tissue, called the *epidermis,* or *cuticle,* and the inner consisting of woody and vascular tissue, named the *liber* or true inner bark.

The *medullary rays* are the thin vertical plates seen connecting the pith with the bark, and like them, consisting of cellular tissue. They are purely cellular, containing no vessels, and probably, like the pith, of no use in the grown-up stem.

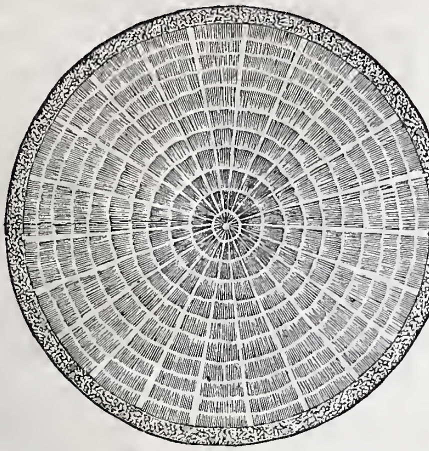
The *woody tissue* consists of fibres and of vessels, occupying the space between the pith and the bark, divided into compact wedge-shaped vertical plates, whose edges rest on the pith and the bark, and whose sides are in contact with the medullary rays.

In the shoot rising from the seed, to become the stem, the cellular tissue of the pith and the bark are in contact; in fact they are but one substance, coated over by the epidermis. But the vascular system, with the woody fibres, as it forms, gradually interposes itself between them, till after a few weeks they are distinctly separated, and in aged trees come to be separated by a thickness of wood occupying several feet. Thus in the twig of one year old, fig. 63, 1, there is seen the pith, surrounded first by a layer of wood, and then by a layer of true bark and a layer of cuticle. The first layer of vascular tissue, formed between the pith or *medulla* and the bark, gets the name of the *medullary sheath,* (fig. 63 *m*, and 59 *m*), it remains next the pith ever after, and the woody tissue goes on to be formed on its outside. But while the first layer of vascular tissue is being deposited, it does not become interposed between the pith and the bark, so as to separate them completely, forming a perfeet eylinder between them; it only displaces a quantity of the cellular tissue whieh joined them together, pushing it aside and compressing it into thin vertical plates as seen in the plan, fig. 57. As the vascular system increases, these plates also increase outwardly, so that a horizontal communication between the centre and the eircumference is still maintained. These medullary rays or plates of the botanists, are called by cabinet-makers the *silver grain.* In transverse sections of an exogenous stem, they are seen as fine lines radiating from the centre to the circumference, fig. 58; in longitudinal sections, they produce that glancing satiny lustre which is more or less discoverable in all woods, and which gives to some a character of remarkable beauty. In many woods of various countries, too, the rays and grain are not straight but tortuous, producing beautiful patterns, as in mahogany and satin wood.

After wood has arrived at the age of a few years, it acquires a colour different from what it possessed when first deposited, beeoming what is called *duramen,* or *heart-wood.* For instance, in the beech it becomes light brown; in the oak, deep brown; in Brazil-wood, green; and in ebony, black. It was originally colourless in all these, and owes its different tints to matter deposited gradually in all parts of the tissue, as may be easily proved by throwing a piece of heart-wood into nitric acid, when the colouring matter is discharged, and the tissue recovers its original appearance. That part of the wood, which being last formed, is interposed between the bark and the heart-wood, is called the *alburnum.*

Even of logwood, the alburnum is as white as fir. The heart-wood is much more durable, and is selected for any work that

Fig. 58.



is wished to last well. The floor of the Royal Exchange in Glasgow consists of planks of the heart of fir, not above three inches in breadth.

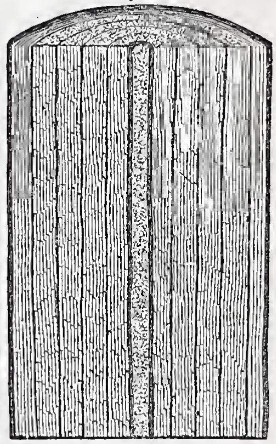
In the lowest of this division of plants, the woody fibres are very few and imperfect. They consist of the vessels or tubes through which the juices are drawn up from the root to the leaves and flowers, imbedded in a quantity of cellular tissue. The stalk of the common greens or kale, (*Brassica*) is an example. Cut it across, when of full size, and the out-side will be woody while the centre will be soft and spongy; split it, and it will tear down with you, showing numerous fibres, which are just its vessels. That delicate substance upon which drawings of butterflies are made so beautifully, called rice-paper, is just the stem of a plant about one inch thick, in which the fibres are so few and far between that it looks like a mass of pith (which it is not, for it has pith in its centre), and it is cut into layers, spirally, with some sharp instrument, to form a thin plate which is then unrolled, pressed flat, and cut into pieces of which the largest are about a foot square. Those plants again, in which the fibres are nume-rous and tenacious, are made useful in a different way. They are steeped in water until the soft cellular tissue between the fibres becomes still softer, and then they are beaten until it is removed, and only the fibres left; in this way flax and hemp are made ready for the artisan who *heckles* or cleans and combs their fibres into regular order, so as to be fit for the spinner.

It was stated at p. 99, that it was impossible to make any guess at the age of an endogenous plant, because it arrived at its greatest thickness very rapidly, and afterwards only con-tinued to grow in height, the new vessels towards the centre of the stem compressing those towards the outside. On the contrary, it would appear easy, theoretically, to determine the age of an outwardly growing tree, the number of rings representing exactly the number of years it had been in exis-tence. On this principle, the figure above would seem to be a cross section of a stem of eleven years growth; but except in the fir, and some other trees of very regular form, accuracy is scarcely possible. We find that in certain circumstances, probably of unequal exposure to the sun and weather, trees grow unequally, one side being much thicker from the centre than the opposite one. It is said also to be much less easy to arrive at a correct conclusion from examining trees in warm climates, than those in a temperate or frigid zone.

A new bark is formed every year, under the old, and therefore next the wood. In consequence of the new bark being continually generated within that of the previous year, it is necessary that the latter, which is pushed outward, should be extensible, more or less, according to the nature of the tree: in some cases the fibres are so far separable as to represent a kind of lace-work, as in one which has hence acquired for itself the name of the lace-bark tree, (*Daphne lagetto.*) Of the Russian lime-tree, the inner layers, when separated by steeping in water, like the flax already spoken of, form the common bass or matting. There exists, however, a limit to the extensibility of the old layers of bark; and when this is passed, the outer bark either splits into deep fissures, as in the oak, the elm, the cork, and most of our European trees, or it falls away in broad plates as in the plane, or it peels off in long thin ribbands, as in the birch.

As there is a layer of bark, consisting both of cellular in-tegument and of woody fibre formed every year, it follows that the age of a tree ought to be indicated by the number of such zones in the bark, just as it has already been said, it is indicated by the successive grains of the wood. But the arrangement of the zones is often so very soon disturbed, and the distinction between them becomes so imperfect, that even where the outermost coating is still entire, it is scarcely practicable to count them; and as soon as the out-side begins to peel off, all cer-tainty of the number of zones disappears. An evident proof that the bark grows from within, is, that if a piece of iron be introduced just into the innermost bark or *liber* of a tree, in process of time it will be found protruded to the surface, and will at length fall away. A more obvious proof is, that a name cut in the bark of a tree by and by disappears; the letters get broader, from their edges separating, by the increased girth of the tree, their depth fills up, by the new growth from within, their edges finally fall off, and they disappear. It was stated at page 35, chapter ii., that the nourishing juices, having risen through the woody vessels, and been purified in the leaves, *descended* in the vessels of the inner bark. This is proved by cutting a ring of the bark out, down to the wood, round part of a tree; the *upper* edge of the cut will be seen to grow, while the lower edge will remain stationary.

Fig. 59.



m

When stems are old, the bark generally bears but a small proportion to the thickness of the *wood;* yet, in some in-stances, its size is very remarkable. The bark of the cork tree is to be seen carried through the streets a couple of inches in thickness, and the bark of an exotic fir has been brought to Europe not less than a foot thick.

Buds are the apparatus by means of which leaves, and branches, and flowers are formed. They are a sort of germ, originating within the stem, from the surface of which they ultimately protrude and become developed. They usually consist of small *scales*, or rudimentary leaves, which are closely wrapt around an axis; this axis being either the ter-mination of the stem, and of course in a line with it, or standing off at a certain angle. Within these external scales there are other leaves, in a still more rudimentary state, which are destined to become more highly developed than those which merely serve for the outer covering, and are either to extend into branches, or to expand into flowers. The outer protecting scales are frequently covered with down, which, perhaps, may aid in keeping out the cold; others are coated with gluten, which is an effectual protection against moisture, as in the horse-chestnut; and, perhaps, the pro-tection from moisture is the end which these scales best fulfil, in most cases, as their closely overlapping arrange-ment would seem to indicate.

Buds may be either *terminal;* that is, at the end of the

stem, or *lateral*, at its sides. A terminal bud is not so general; for, when it does occur, the growth of the stem or branch is there put an end to, the bud breaking into a head of flowers. In most cases, buds are formed about the place where the leaves unite with the stem; and generally they are situated immediately above the *axil* (armpit) of the leaf, or place between the stem and the leafstalk, as is the case with the lower one in the figure. Buds may, however, be developed, under certain circumstances, from any part of the stem; such are called irregular or adventitious buds, and are always found on the end of a medullary ray, by which their connexion with the central pith is maintained.

Fig. 60.

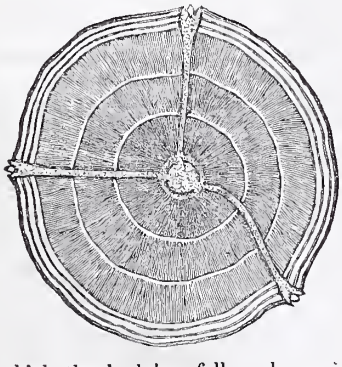
While yet very young, branches are denominated *shoots;* and when they arise from underground stems, and their leaves, instead of becoming developed, put on the form of scales, as in the common asparagus, fig. 61, the shoot is called a *turio.*

Fig. 61.

Branches are found placed on the stem of very many plants, especially of those which belong to the division of dicotyledons. But monocotyledonous plants, which are endogenous, (see page 98,) do not so generally put forth branches, and most monocotyledonous trees, as the palms, are without them. Branches have precisely the same organization as the stem, and they may, in fact, be considered as so many partial stems ingrafted on the main trunk. As they originate from buds, their arrangement round the stem will depend upon the arrangement of the leaves. because the buds are placed in the *axils* between these and the stem. Branches are never, however, so symmetrically arranged as leaves, because a great many buds are never developed at all. This want of growth depends on the unfavourable circumstances under which many are placed, being deprived of a sufficiency of air, of moisture, or of light. The consequence is, that those which originate on the lower parts of the stem, are either much stunted, or become abortive.

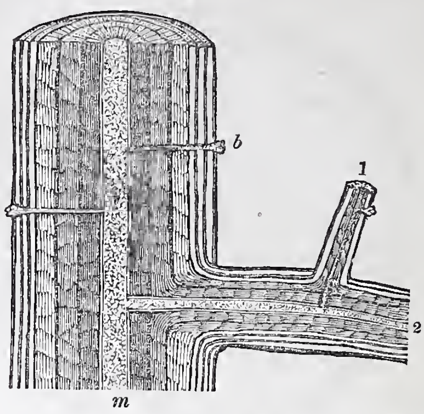
When a bud has been formed, but has not grown out into a branch, it still continues to live, and is carried out with the increasing bulk of the stem; awaiting at the surface for a proper opportunity, which may enable it to *break* into a branch. This is familiar to every gardener, and is the principle on which he regulates the pruning of his trees. If a transverse section of a stem, fig. 62, be made at the point where an undeveloped bud is seen to protrude, it will show

Fig. 62.



the course which the bud has followed, passing from the centre outward, marked by a line or wake, traversing the several layers. Hence, *branches* of the same age and size may be originated from *buds* which have been formed at very different periods of the tree's growth. This is an additional cause to those mentioned in last paragraph, tending to destroy the symmetry, which branches might otherwise have exhibited in their arrangement around the stem. The accompanying fig. 63, shows a bud, seated on a branch 1,

Fig. 63.



which is one year old; this branch is placed on another 2, which is two years' old, and which originated from a bud 1, the same age as *b*, which has not yet become developed.

The different styles in which the branches stand out from the trunk have been already illustrated by four figures on page 97.

When a bud is imperfectly developed, it sometimes becomes a short branch, very hard and sharp at the extremity, and is then called a *thorn*, fig. 64. This must not be confounded

Fig. 64.

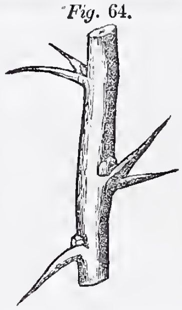


Fig. 65.

Fig. 66.

with a prickle, from which it differs in having a considerable quantity of woody tissue in its structure, and a true bark, and is as much in communication with the central part of a stem, as the branches are. Thorns occasionally bear leaves, as in both the Hawthorn and the Sloe. In domesticated plants they often entirely disappear, as in the Apple and Pear, the wild branches of which are thorny.

Prickles figs. 65, 66, are stiff, opaque, conical projections, formed of cellular tissue, ending in a sharp point, and closely resembling stiff hardened hairs. They have no connexion with the woody tissue, but can be separated from the bark, on which they leave a scar. They are found on almost all parts of plants, but their usual place is on the stem and branches. We are familiar with them on the Rose and the Bramble.

Hairs like prickles, are unconnected with the wood, and are merely appendages seated upon the outer bark.

MATHEMATICS. 161

PRINCIPLES OF ALGEBRA.

PRELIMINARY REMARKS.

ALGEBRA is a branch of mathematical science, in which the reasoning employed in the solution of all problems relating to numbers, is generalized and abridged by the use of general symbols of quantity, and the conventional signs of operation employed in arithmetic. By Newton it is called universal arithmetic and, in some respects, the appellation is appropriate; but

between the two methods, there is this distinction : in arithmetic, the symbols of number have a determinate connexion agreed upon, and universally recognised ; and our object is to combine them together according to certain rules. In algebra, on the other hand, the symbols employed have no determinate connexion, nor is it a numerical result which we seek to obtain, but the manner in which the several numbers enter into the calculation. By working an arithmetical operation, we obtain a result, the value of which is known when the value of the unit is known. But the algebraical result of an operation is independent of all numerical convention ; it is simply a general expression in symbolical language of the arithmetical operations which must be performed to obtain the numerical answer ; it is in fact the arithmetical rule by which all questions of the same class may be resolved. Where algebra terminates, arithmetic begins: the former investigates the conditions of the problem, and discovers the relation subsisting among its terms ; the latter deduces, by a special application of the principles evolved to particular numbers, the numerical result.

This at least is a view of one great branch of algebra, expressed it must be allowed in very general language. To render it more explicit, let us descend to particular examples of the two species of calculation. In the first place, let it be required to add together the three numbers 4, 3, 7 ; we readily find that the sum is 14. Now, this result, 14, is an isolated quantity ; it in no way indicates the nature of the operation of which it is the result; for aught that it shows to the contrary, it may have been obtained by adding together 7 and 7, or 6 and 8, or any other pair or series of numbers whose sum is 14 ; and it might, moreover, have been found by any other arithmetical operation upon certain numbers, besides addition. But if, instead of combining the three given numbers into one sum, we indicate simply the manner in which the calculation is to be effected, and write $4 + 3 + 7$, we preserve in this, the enunciation of the question, the successive steps of the operation to be performed, and the respective quantities which enter into the calculation. In prefixing in the same manner to all the quantities which compose the terms of a problem, the particular signs which express the arithmetical operations to be performed upon them, we are able to represent the result by means of the given numbers and the known symbols of operation.

This is one step in algebra ; but in passing from one system of numeration to another, the numerical expression varies in its meaning. This, besides being a source of inconvenience in particular cases, would limit our reasoning to particular examples, and take away from the investigation its most essential character. To obviate this, it is necessary to render our results independent of all convention founded upon an arithmetical model ; in other words, we must represent the quantities reasoned upon by such general symbols as the letters of the alphabet. To announce in this general way the sum of three numbers as above, we write $a + b + c$, where a, b, and c, are symbols of numbers having no reference to any system of arithmetical numeration.

For the purpose of showing the distinction still more clearly, it may be observed, that in all questions the solution consists of two separate processes ; the first has for its object the discovery by which of the four fundamental operations the unknown result may be determined from the numbers given in the question ; the other consists in the application of these rules. The first is an algebraical process ; the latter belongs to arithmetic ; the first is entirely independent of any system of numeration, aiming entirely at the development of the conditions of the enunciation ; in other words, of the relations subsisting among the numbers involved. As an example, let it be required to divide the number 13 into two parts, such, that the first shall surpass the second by 5. Here the second part is equal to the first diminished by 5 ; or the sum of the parts diminished by 5 is equal to double of the first part, or to double of the first *less* 5. But from the enunciation of the question, the sum of the parts is equal to 13, and consequently double the first is $13 + 5$ or 18. The first part is consequently 9, and the second part is 5 less, that is 4.

It is obvious that we might resolve any other question of the same nature by the same species of reasoning ; but in taking a new set of numbers, it would be necessary to commence the process anew. By employing general symbols, we obtain a solution equally general, and applicable to all numbers which may be involved in a question of like conditions. Thus let a denote the greater of the two numbers, and b the less ; in applying to these symbols the reasoning employed in the case of 13 and 5, we easily prove that the first part sought is equal to the half of the sum of the two numbers a and b. This sum is $a + b$, and its half is $\frac{a+b}{2}$ which is a general expression for the first part sought. Applying the reasoning to the second part, which the question supposes to be less, we find that it is equal to half the difference of the two given numbers ; now, the difference is $a - b$ and the half $\frac{a-b}{2}$ which is an expression for the second part sought. Now, whatever numerical values we give to a and b, it is only necessary to substitute them in these expressions to find the values sought.

One great advantage of algebra is, the simplicity of its language. Common language might in some simple instances be employed, but in general the expressions are too prolix to be convenient. Take as an instance the enunciation of the following simple and short proposition :—" The greater of two numbers is equal to half their sum increased by half their difference." This, expressed symbolically, is shortly—

$$m = \frac{m+n}{2} + \frac{m-n}{2}$$

in which m is supposed to be the greater of the two numbers, and n the less. This expression, moreover, enables us at once to see that the proposition is true ; for on the right of the sign $=$ we find $\frac{n}{2}$ once added and once subtracted, consequently it might without affecting the truth of the expression be expunged, leaving

$$m = \frac{m}{2} + \frac{m}{2} \text{ that is in effect } m = m.$$

Not only does algebra give a facility in seizing upon the conditions, but it reduces the reasoning employed in the operations in some measure to a mechanical process. The grammar of its language is simple and precise, and the signs employed in expressing its relations are very few in number. It is a branch of analysis from which many are deterred by an idea of its difficulty ; no prejudice could possibly be more erroneous. Assuming that the student has attained a good knowledge of arithmetic, especially of fractional arithmetic, he has no positive difficulty to surmount in the attainment of algebra. He has simply to divest his mind of the limited notion that numbers can only be represented by the conventional symbols 1, 2, 3, 4, &c. ; these are necessary to the expression of quantity when we consider it composed of determinate units. But in reasoning upon the relation of quantities, it is not necessary to refer them to any system of numeration ; and it is equally clear that we may speak of their addition, subtraction, multiplication, and division, without knowing that they are composed of any certain number of arbitrary units. The numerical symbols are of the utmost importance in expressing with brevity and distinctness an arithmetical result ; but in the logical investigation of the principles of calculation, they are an incumbrance, and are replaced with advantage by other symbols of a more general kind.

Chapter I.—Addition and Subtraction.

1. In a strictly arithmetical sense, there is in algebra neither addition nor subtraction, the operations are merely indicated. A quantity is said to be added, when it is joined to another by the sign $+$, and subtracted when it is joined by the sign $-$. Thus, a is added to the quantity P in the expression $P + a$, and subtracted from it in the expression $P - a$. Giving to P and a in the expressions the particular values 12 and 5 ; then $P + a = 12 + 5$ or 17, and $P - a = 12 - 5$ or 7.

2. If to the sum $P + a$ we add a, we obtain in the same way the new sum $P + a + a$. Here, although we do not know the value of a, we know that, be it what it may, it is added twice to P; the sum $P + a + a$, is therefore equivalent to P + twice a; but instead of the word *twice*, we use for brevity 2, and write $P + 2\,a$. This number 2 is called the *coefficient* of a, and is a concise mode of denoting the number of times that the quantity a has been added.

Similarly, $P + a + a + a + a = P + 4\,a$. And $P + 4\,a + b + b + b = P + 4\,a + 3\,b$. In these a has a coefficient 4, and b a coefficient 3.

3. Again, if $4\ a$ and $6\ a$ be added to P, and $5\ a$ and $2\ a$ be subtracted from the same, the whole result will be expressed by

$$P + 4\,a + 6\,a - 5\,a - 2\,a.$$

And here, whatever may be the value of a, we know that it is added $4 + 6$ or 10 times, and subtracted $5 + 2$ or 7 times. Consequently, we might write instead of the above expression,

$$P + 10\,a - 7\,a, \text{ and this is } P + 3\,a,$$

for, without inquiring into the value of a, it is clear that to add it 10 times, and subtract it 7 times, is in effect to add it three times; that is, to write $3\ a$ for $10\ a - 7\ a$.

This process of combining several *like terms* into one may be called *Reduction*. From the preceding example, it will be observed to consist in collecting together those coefficients which have the same sign into one sum, and those which have the opposite sign into another; and subtracting that which is numerically less from that which is numerically greater. To the difference is prefixed the sign of the greater sum. Thus,

$P+3\,a+2\,a-4\,a=P+a$	$P-12\,x+9\,x+2\,x=P-x$
$P+x\ \ +7\,x-2\,x=P+6\,x$	$P-\ 6\,a+3\,a-6\,a=P-9\,a.$

When no two terms of an expression are exactly the same as to letters and the number of letters in them, the reduction cannot be carried further. For instance, $a\,b + a\,c$ does not admit of reduction, although a be common to both terms; the same is also true of $a + a\,a$, which is neither $2\ a$, nor $2\ a\,a$. The reason of this will be explained subsequently.

4. It may also be observed, that, since we cannot take a greater number from a less, any expression such as $3\ a - 4\ a$ is impossible; for, whatever $3\ a$ may be in value, $4\ a$ must be greater. In future, we shall find it necessary to investigate the meaning of such expressions, which frequently arise in the solution of questions; but, in the mean time, we may regard them simply as directions to do what cannot be done. Such an expression as $a - 2\,a + 3\,a$ is, however, possible; it is merely an improper form of $a + 3\,a - 2\ a$, which, reduced, is $2\ a$.

5. When an expression such as $b + c$ is enclosed in brackets, it signifies that its whole result stands in relation to the symbols connected with it, as if it were only one letter. Thus, $a + (b + c)$ means that we are to add to a not only b, but $b + c$. Now, adding b and then c, the sum is $a + b + c$. In like manner, the expression $a + (b - c)$, signifies that we are to add to a, not b, but a quantity less than b by a quantity c. To find the sum, we must therefore first add b, and afterwards subtract c, whence we get

$$a + (b - c) = a + b - c.$$

From this, and the preceding instance we conclude, that *an expression in brackets preceded by the sign + will not be altered in value if the brackets be struck out.* They, besides, furnish us with a general rule for the addition of algebraical expressions; it is this:—

Connect all the terms of the given quantities by their respective signs, and make all the reductions which are practicable. It must, however, be observed, that when a quantity is not preceded by any sign, + is always understood, and when a lateral quantity has no coefficient, 1 is always understood. Thus, a is the same as $+ 1\ a$. The following is an example of addition and reduction:—

Add $a - b$; $a + 2\,b - c$; $2\,a + 2\,b - 3\,c$; $2\,a + 3\,b + 4\,c$; and $2\ c - 3\ b$, together.

Ans. $a - b + a + 2\ b - c + 2\ a + 2\ b - 3\ c + 2\ a + 3\ b + 4\ c + 2\ c - 3\ b$, which, by reduction, becomes $6\ a + 3\,b + 2\,c$.

6. When the quantities to be added are complex, the process of reduction is much facilitated by writing the *similar* terms in vertical columns. The foregoing example is thus arranged on the right, and the reduced sum is found by setting down the value of each column. In arranging the terms in this manner, the only care necessary to be taken is, to preserve to each term its proper sign. This may give rise to improper forms of expression, such as $-3\,b + 2\,c$, but will introduce no error into the final result; for in this arrangement the terms have reference only to the columns in which they are placed, and it is obvious, that the columns themselves may be disposed of in any order. In arranging the columns, the alphabetical order of the letters is commonly preferred.

Terms arranged.

$$\begin{array}{rrrr}
 & a & -\,b & \\
 & a & +\,2\,b & -\,c \\
 & 2\,a & +\,2\,b & -\,3\,c \\
 & 2\,a & +\,3\,b & +\,4\,c \\
 & & -\,3\,b & +\,2\,c \\
\hline
\text{Sum,} & 6\,a & +\,3\,b & +\,2\,c
\end{array}$$

7. It has been shown that an expression in brackets, when preceded by the sign + admits of the brackets being struck out, without the value of the expression being affected; but if the bracketed expression be preceded by the sign —, the case is different. Let the expression be $a - (b + c.)$ Here we are required to subtract from a, not b, but the sum of b and c. If then we subtract b, making $a - b$, the expression is too great by c; hence c must also be subtracted, giving

$$a - (b + c) = a - b - c.$$

Again, let the expression be $a - (b - c)$; if we now subtract b giving $a - b$, we will have subtracted too much by c, for it is not b which we are required to subtract, but a quantity less than b by the quantity c. Consequently, $a - b + c$ is the true result, or

$$a - (b - c) = a - b + c.$$

From this we learn that *when an expression in brackets is preceded by the sign —, the brackets may be struck out,* IF THE SIGNS OF ALL THE TERMS WITHIN THE BRACKETS BE CHANGED, *namely, + into —, and — into +.* This rule leads directly to the mode of subtracting expressions which have more than one term. For applying the remark respecting the relation of quantities put within brackets, we may obviously, in the first instance, express the given subtraction in that form, and afterwards strike out the brackets, and change the signs as directed above. Thus, suppose that it is required to subtract $a + b + c - d$ from P; the subtraction is indicated by

$$P - (a + b + c - d),$$

which becomes, when the brackets are struck out, and the signs changed,

$$P - a - b - c + d.$$

Similarly, let it be required to subtract $5\ a - 5\ b + 6\ c$ from $6\ a - 3\ b + 4\ c$; the expression is

$$6\,a - 3\,b + 4\,c - (5\,a - 5\,b + 6\,c),$$

and taking away the brackets, we get

$$6\,a - 3\,b + 4\,c - 5\,a + 5\,b - 6\,c,$$

which, by reduction of like terms, becomes $a + 2\,b - 2\,c$.

The following, then, is the rule for subtraction:—

Change the signs of all the terms of the quantity to be subtracted, (considering + as the sign of the first term) and annex the expression thus changed to the expression from which the subtraction was to be made, and make all practicable reductions as in addition. To facilitate reduction, the like terms of the two expressions may be written under each other as in the following examples:—

$$\begin{array}{lrrrl}
\text{From} & 4\,a + 3\,b - 3\,c & & 5\,m - 7\,p + 2\,r - 3\,x & \\
\text{Take} & 3\,a - 3\,b + 4\,c & & 8\,m + 2\,p + 2\,r - 5\,x - z & \\
\hline
\text{Rem.} & a + 6\,b - 7\,c & & -3\,m - 7\,p \qquad + 2\,x + z &
\end{array}$$

This last result we prefer writing in the form

$$2\,x - 3\,m - 7\,p + z, \text{ or } 2\,x + z - 7\,p - 3\,m,$$

as the + sign is understood when not expressed, but the sign — must always be expressed when a quantity is affected by it.

The student may arrange the following question for himself:—

$$\begin{array}{ll}
\text{From} & 8\,a - 5\,b - 3\,c - 7\,d + 5\,e - 8\,f + 3\,g + 17\,k + 3\,h - q \\
\text{Take} & 3\,c - 2\,p - 5\,b + 2\,d - 7\,f - 5\,e + 3\,h + 9\,g - 5\,k + 12 \\
\hline
\text{Rem.} & 8\,a - 6\,c - 9\,d + 10\,e - f - 6\,g + 22\,k + 2\,p - q - 12
\end{array}$$

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8. It may be observed that since the results in addition and subtraction are independent of the order in which the terms of the expressions are written, it is not necessary to inquire whether an expression be written in a possible or impossible form. Thus it would be immaterial in either of the operations whether we wrote $2 - 5 + 7$, or $2 + 7 - 5$: the rules apply equally to either form and the final result is not affected.

It may also be observed, in passing from these rules, that those terms which have the sign + of addition prefixed, are called *additive* or *positive* terms; and those which have the sign — of subtraction are called *subtractive* or *negative* terms. These names are of frequent use.

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HISTORY.

CHAPTER XIV.

OF THE GREEKS.

One of the great objects which, in the course of these sketches, we have always wished to keep in view, is the advantage and necessity of the portion of the history selected as illustrative of the origin and growth of practical systems of government, morals, and religion, by a natural, unbroken, and gradual development. The origin of these was in the Roman republic; the most advanced stage they have yet reached is in Europe, and states of Europeans, wherever they exist. We have traced their progress in the Roman republic. Before proceeding with the next stage—the Roman empire, we have been under the necessity of pausing to take note of certain foreign particles which were received into the body of the state, and assimilated to it as food is assimilated to the human body. These particles were the territories and different people among whom Roman sway succeeded to Greek ascendancy. To understand their constitution aright, it was necessary to distinguish between the states of Greek origin and those which had succeeded to the Greeks, upon their victory over the Persian monarchy, so long their antagonist power. The Persian monarchy has been shown to have been an encampment of the Medo-Persian clans under their hereditary general among conquered nations, from which they exacted tribute, and which they used in their wars. There have been presented to the notice of the reader in the review of Egyptian and Jewish history, specimens of systems of laws, morals, and religion, which had grown up among those subjected states, and which combined under the Medo-Persian dynasty to regulate the relations of these states towards each other. With reference to the Greeks, the Persian state was one: with reference to one another, its members were a congeries of states, differing in institutions, laws, and customs. We now proceed to the history of the Greeks themselves.

This branch of the subject falls naturally under two eras. 1st, The history of the Greeks from the date of the earliest records, down to the reign of Alexander the Great, which commenced in the year before Christ 337. 2d, The history of the Greeks from that period down to the assimilation of all the original Greek and subsequently Hellenized states with the Roman state, a period corresponding pretty nearly with the overthrow of the Roman republic by Cæsar.

The earliest narrative source of information which we possess respecting Greece, is derived from the works of Herodotus, which were read to the Greeks at the Olympic games, about the year A. C. 447. From that period down to the termination of the second era, we have a tolerably unbroken line of contemporary authors. Thucydides may be regarded as the continuation of Herodotus, and Xenophon of Thucydides, while the Attic orators and philosophers fill up the space that intervenes between the latter and Alexander. Fragments of the journals, and more systematic historians contemporary with Alexander, have been preserved. After this, Polybius, the writers of the school of Alexandria, and lastly, Strabo, and Plutarch of Chæronea. All these writers are completed and illustrated by what has come down to us of a contemporary literature unsurpassed in originality, beauty, and variety. Greece is surpassingly rich in that class of monuments which, having inscriptions traced upon them, combine the characters of literary and monumental sources of history; and its monuments of architectural and sepulchral art, as they are unsurpassed in number, are unequalled in beauty. With most other early nations, their literature is interesting only as a source whence we learn their history. The history of Greece is of value chiefly as a means of enabling us to enter more thoroughly into the spirit of its literature. With these general remarks we shall proceed to the subject of Grecian history.

I. The first period of the history of independent Greece, (we use the word independent in the same sense as when treating of Egypt and Judea, to indicate freedom from foreign influence merely), extends from the earliest times of which we have any record, to the commencement of the reign of Alexander, in the year before Christ 337. It is only during the last 106 years of this period, that we are possessed of contemporary historians. This is a disadvantage which the independent Greeks share with the Roman republicans. But the Greek historians do not bear the same undeniable tokens of close adherence to the original registries and archives as the Romans do. One cause of this is the semi-political character which history from the beginning assumes among the Greeks; another is the subjection of the Greeks to the Roman sway—the Roman law being the public and pervading law, was more studied, and consequently, its monuments were sedulously preserved under the empire; another, the fact that Greece was a family of tribes æquipotent, which shifted and changed their seats and importance, and ultimately amalgamated, while Rome was only one, which finally absorbed its kindred tribes into the full grown state. The early portion of this period of Grecian history—the records of the circumstances under which the peculiarities of Greece developed themselves and hardened into form—are in all probability irrecoverably lost. The writers to whom we are indebted for what vague notions of them we possess, seem to have themselves inherited very indefinite and unsteady notions on the subject, and our necessarily imperfect understanding of them, confuses it still more. What can be guessed rather than inferred from these sources, is briefly as follows:—

The original seat of the Greek tribes must to all appearance have been on the mainland and islands, at the extremity of the Mediterranean. Here, within a space of five degrees of the earth's surface, are comprehended all the mainland of that portion of Europe lying between the gulf of Adria and the Egean sea, north of a line drawn from Mount Olympus on the latter to a little north of Corfu on the former, constituting the Peloponnesus, or as it is now termed, the Morea. This, with the island of Crete, and all the numerous islands which form that archipelago, constituted the seats of original Greece, not only at the time at which contemporary history begins, but at the most remote period to which tradition allows us to waft a conjecture. The earliest metaphysical legends of Greece mirror the physical features of this country; nay more, they retain traditional traces of elementary convulsions of which all history is silent, but strong indications of which may still be read in the superficial forms and internal strata of island, cape, and mainland. The flood of Deucalion corresponds with a disruption of the land between the Bosphorus and the Egean sea, sending the surcharged waters of the former which had previously found vent only by exhalation, in one rending and overwhelming flood, over the plains of Greece. The fabulous Typhon, and the equally fabulous Chimera, harmonize with the features of the land; the localities assigned to which are in the inland of Asia Minor, which wears to this day the appearance of a vast extent of slumbering volcanic region; and while the observations of the geologist confirm the truths of ancient elemental war in that territory, the thunder-god—the supreme national deity of the Greeks, could nowhere find a more appropriate residence than in the mountain peaks of the land which they inhabited. These are the mythological legends of Greece, which bear the most unequivocal marks of being native to the soil, or, like the Venus of its mythology, sprung from the sea which laves its shores. They are, however, but faint indications, inextricably blended with ingredients of foreign admixture. In addition to the indigenous gods of Greece, divinities had been imported from Egypt and Phenicia—the Athene of Athens, the Venus of Paphos, had not only had altars erected to them, but had been worshipped long enough to allow of the mode of their original introduction being forgotten, and of their being ingrafted by fictions of paternity upon the stock of the original gods; nay, in Oceanus and Saturn, we have indications of the memory of older gods, whose worship had been banished to make way for the new denizen of Olympus. But there is still a more striking feature in the theogony of Homer. In the reflections upon *Anayke*, (necessity) who controls gods as well as men, and in the vague but grand allegory of the golden chain binding together heaven and earth, men and gods, their fates and actions, we recognise the struggles of mind to free itself from the whole bewildering multiplicity of a polytheism which had been forged by imagination upon the suggestions of vague emotion, and which had lost in intensity of feeling in exact proportion as it gained ground in precision of form. The composer of the poem had outlived the belief in the national worship; nay, more, he seems to have lived and conversed with others as far advanced as himself. The philosophic spirit which reached its full growth in Socrates and

Aristotle, was already rapidly approaching to maturity. It is in vain, therefore, we look to the highly artificial and lifeless though beautiful mythology of Greece, for more pregnant traits of the original localities of the Greek tribes than have been already mentioned.

It has been universally conceded that all the Greek tribes are generally sprung from the Pelasgi and Hellenes; but whether these two races spoke the same, or an entirely different dialect, is unknown. Herodotus confesses his ignorance on this point. He, however, regards Ionic as synonymous with Pelasgic, and Doric with Hellenic. He assigns as the early seats of the Hellenes the district extending from a little north of the Straits of Thermopylæ to the borders of Macedon, first shifting gradually northward, then turning southward, and penetrating into the Peloponnesus, which they finally occupied. The Pelasgi, he tells us on the other hand, were a stationary race; he also informs us that the inhabitants of Attica and Ionia were of this race—a fact partly corroborated by a passage at the termination of the second book of the Iliad, which is acknowledged to contain an accurate and authoritative description of the distribution of the Greeks. The names given are various, but there are three which designate the whole host, Hellenes, Achaii, and Danai. The notice taken by Homer affords rather scant materials to build upon; but, combined with what is related by Herodotus, they seem to point out the original seats of the Hellenes and Pelasgi, at the extreme north of the space we have allotted to the Greeks; the Hellenes to the west, and the Pelasgi to the east, both forming the sources of parallel streams of immigration towards the south-west, peopling the mainland, the Peloponnesus, and the islands at the mouth of the Gulf of Corinth, with Hellenes, and the shores of Asia Minor, the promontory of Attica, and the islands of the Archipelago with Pelasgi. Every thing, in fact, combines to support the notion that the Greeks were mainly an unmixed people, splitting into more and more numerous clans as they increased in number, the Pelasgi and the Hellenes being the oldest.

The manner in which the Greek clans diffused themselves can be clearly traced. The records of the foundations of many of their cities have been preserved, and the plan continued for at least the first hundred years of the period during which we possess a temporary history. The Greeks, like the Latins, and other Italian tribes, inhabited hill forts, and cultivated or protected the land in the immediate vicinity. From the nature of their towns or cities, they could not extend their limits when their population became redundant. They were obliged to send colonies. Sometimes, when two or three, or even more, neighbouring cities, found themselves relieving the plethora of human existence, without being exactly able to found a powerful city, they combined their forces. The swarms sent off from several cities founded only one new city, which was called a colony of that which contributed the greatest number of inhabitants, and furnished the institution with a leader. The colonists from each state were registered in one tribe, and this is the origin of the tribes which we find playing such an important part in the constitution of many Greek cities, as for example that of Athens. The relations of colonies to the parent state were various. Sometimes the colonists were even expelled in consequence of some revolution, and then there was no relation preserved whatever, only a family resemblance in laws, institutions, and religion. Sometimes an acknowledgment of relationship was kept up through the instrumentality of certain religious rites only. Sometimes when the colony was weak, and when it was surrounded by powerful inimical neighbours, protection was afforded in consideration of a present sent, or the direct payment of a tribute. When the tribes within a colony were nearly equal in number, old associations would prompt each to cling to its own cognate state, and sometimes the internal quarrels of a colony would occasion wars and feuds between the parent states. Sometimes wars between the parent states would produce intestine commotions in a colony. The relations between cities thus connected was more that of reliance than national incorporation—more a matter of international than of municipal law. Each only legislated for itself in its own internal affairs; it was only with a view to mutual defence against external enemies that they were combined.

In this manner did the Greeks extend themselves by degrees all around the shores of the Hellespont, to the Propontis and the Bosphorus: thus did they become occupants of Sicily and the southern extremity of Italy, of Cyrene, and even make several settlements in Syria, and in the Delta of the Nile. In all these regions Greek cities sprung up and flourished, filled with a restless, enterprising, ingenious race. Self-governed within itself, each city was continually altering its constitution as feeling or circumstance suggested. Throughout all of them we can observe the changes following a certain organic law. For a while, the leaders in founding the city, and their descendants after them, were regarded and obeyed as a natural aristocracy. When the inevitable corrupting influence of that form of government upon the possessors of power began to display itself, the people rose in wrath and freed themselves, and organized, or attempted to organize, a democracy. The most of the citizens felt that they had been ill-governed; but this was far from implying that they understood how to amend themselves. The ill-balanced state was continually agitated by struggles of the old aristocracy to resume their power by efforts of selfish popular leaders to rule for their own personal advantage, and by desperate—because blind—struggles of the people to relieve themselves from the evils they felt, but could not account for. In those cities which were composed of a mixed people, this contest of factions often took a family turn. In such cases the rival powers were not unfrequently supported in their respective claims by the parent states; in these quarrels the colonies also became involved, and thus from a domestic broil arose a general war.

Such a state, though far from tranquil or comfortable, was by no means unfavourable to the development of the intellectual powers. In such a school, the first rude notions of civil polity and morality became more comprehensive, refined, and definite; and hence, 100 years before the date of the oldest contemporary history, the Greeks were sufficiently advanced to admit of Lycurgus projecting and establishing a highly artificial model of a state. The Lacedemonian institutions were doubtless tinged with barbarism, yet, withal, they demonstrated that knowledge is power; for, by habitual calculation of the means to attain the one end they had in view, they kept themselves for five hundred years the most powerful among the Grecian states. Lycurgus had the luck to hit the exact time when his townsmen were capable of being modelled into his ideal of good citizens. One generation being thus sophisticated, the next, having the character impressed upon its infant mind, was secure. But in these busy stirring times of Greece, a few years of the most effective education of events had placed the rest of Greece on too high a scale of civilization to be made Lacedemonians of; they had become too refined in their tastes—too conscious of their individual rights—too humane. Draco was the last that tried it, and his failure was signal. Solon, about the middle of the sixth century before Christ, was more awake to what the times required, and what men were capable of accomplishing. "He gave the Athenians, he said, not the best laws that were capable of being made, but the best that could be carried into operation. Men were children in the days of Lycurgus, in the days of Solon they must be convinced."

In proportion as the legislator grew obsolete, and the mere administrated rules stepped into his place, the philosopher became prominent. Moral philosophy assumed under Solomon in Judea—and which, indeed, is its earliest form in all nations—a collection of weighty and important precepts, each expressed with epigrammatic terseness, in order to impress it with the more certainty upon the memory. Some loose notions of physical science had been added by the wise men of Greece, philosopher being the term of a later day. Before the time of Herodotus, Thales of Miletus had foretold, with considerable vagueness, an eclipse of the sun. Anaximander, a disciple of that philosopher, is said to have mounted a globe to represent the surface of the earth as known at his time. These facts show certain advances in geometric science, as well as the mere observation of the heavenly bodies. These indications of science make their first appearance in Ionia. Herodotus represents Aristarchus the tyrant of Miletus, as astonishing his Spartan visitors with his geographical learning. It is among the most commercial of the Greeks that we find this knowledge developed; and their own traditions frankly admit that they derived the use of letters from the Phœnicians; the knowledge of divisions of the day, and the art of constructing dials to the Chaldeans; and their first rude notions of mathematics—perhaps only of land measuring—to the Egyptians. It is evident, from some notices in Herodotus, that they had some notions of architecture,

and of the mechanical arts, although in all these they stood far behind the neighbouring nations.

Before closing this hasty sketch of the progress made by the Greeks, up to the time at which they became possessed of a contemporary history, we may mention an important feature, in the early ages of Greece, of which no trace remains in history, viz., the desire common to all rude nations for repressing the violent passions of men, by the institution of religious ceremonies, and, to strengthen the power of the priesthood, the admission of all the bolder and better spirits in the mysteries with which they had invested their observances, in order to induce them to make common cause with these functionaries. Their institutions degenerated in course of time into a mere engine of power in the hands of the privileged classes. Too much light let in upon them would have destroyed them, and in them, therefore, the philosopher found powerful and dangerous enemies whom it was necessary to conciliate; much of their learning was therefore confined to those who had undergone the ceremonies of initiation. When speaking, therefore, in public, with a view to excite curiosity, and attract fresh interests, they spoke in bold metaphors; hence a character was given to Greek philosophy in its very infancy, which more or less clung to it through its whole career.

We have now arrived at the period when the light, reflected from a contemporary historian, breaks in upon us. Some time before this, an important and pervading change had taken place in the relations of the Greek cities. It was in the nature of things to expect, that amid such a chaos of almost co-ordinate states, some should outrun the others, and gain an ascendancy over them. Lacedemon had had this in virtue of its institutions; Athens, Corinth, and Rhodes, in virtue of the activity and consequent civilization awakened among their citizens by favourable circumstances. The war between the Persians and the Greeks modified and further concentrated this natural tendency of power into a few hands. The republican institutions of the Greek cities, and the native energies of the Greek race, opposed a resistance to the Persian lust of dominion, which it had experienced in no other except in that of Jerusalem; and the Greek cities did not stand like Jerusalem alone—they were aided in their struggles for independence by kindred and allied cities. When they heard of the Persian myriads, Athens and Lacedemon stood erect and undaunted. The latter sent her sons to lie in the gap at Thermopylæ, in order that Greece might have time to rally. The former burned their houses, and betook themselves to a home on the unstable bosom of the deep. It was but a few of the Greek races that rallied round these heroic states, but they were enough in themselves. The repeated checks of Salamis and Marathon were enough to teach even the vanity of the Persian despot, that Greece, animated by such spirits, was unassailable by all his physical force. This was an era in the history of man. Valour had been shown before, and skill in battle; nations had executed incredible achievements for plunder to themselves, or false glory to a leader; but this is the first recorded instance (and thank God not the last), of the power that swells the freeman's heart, and nerves his arm when, one of a small host, he strikes "for happy homes and altars free" against myriads of rapacious hirelings.

From the taking of Sestos by the Greeks, which was considered the termination of the Persian war, in the year B. C. 478, to the battle of Chæronea, which made Alexander master of Greece, in the year 338, A. C., only 140 years elapsed, and, of that, considerably more than a third was occupied with one protracted struggle for ascendancy between Athens and Lacedemon. The spirit of the conquered despot seemed to possess his conquerors equally. It was this, the state of utter prostration to which Greece was reduced by this long struggle, and the other wars which arose after it, that enabled Philip and Alexander to subdue it to their will.

The history of Athens, is during this period, the history of Greece. The history of Greece is its literature; and Athens was at this time to Greece, what Paris is to France.

The exact sciences had so far advanced in Athens at a very early period of this era, that an Athenian astronomer was enabled to introduce important references into the calendar. He took for the basis of his calculations an observation of the solstice, in the year A. C. 432; Plato afterwards pronounced mathematics as the only sure preparation for the study of philosophy. Dicæarchus, a scholar of Aristotle, rectified the projection of the sphere by Anaximander. Intellectual kept pace with physical science. Socrates was the first great teacher of a utilitarian system of morals. The useful and the beautiful were the two parallel lines which, according to his doctrine, hemmed in the strait path along which good men ought to walk. His disciple Plato ingrafted these ideas upon an imaginative mind, and a disposition the very reverse of his master's. Socrates walked in love; in the weakness of human nature he saw nothing more than occasion for a good-humoured laugh, which, by amusing him, made him almost sympathize with the occasion of it—a man among men, he good-humouredly strewed on every side his receipts for making men good and happy. The more poetical soul of Plato shrunk fastidiously from the contact of vice; his bold speculating genius sought to devise systems of morals and felicity elevatory of the race as well as the individual. He proceeded upon the principle—make wise, and goodness will follow. He seems to have cared little for the knowledge of details, which is the fruit of observation—the abstract sciences were what he most affected. Like all philosophers, from Lycurgus down to Mr Owen, who have sought to make man something different from, and better than what he is, instead of resting satisfied with skilfully weighing what is good in his nature, and habituating him to repress as far as possible what is bad, the theories of Plato are false to an extent that is sometimes ludicrous; but his life was in the right, and so was that of most of his followers. Aristotle was more of an abstract thinker. He loved knowledge for its own sake, and brought to the task of acquiring it, a most comprehensive intellect, and one at the same time singularly skilful in classification and arrangement. He and Plato may be regarded as having given that form to science which it retained with little alteration, both in the Christian and Mahometan world, down to the 15th century.

Nor were they and their master Socrates mere trainers of scholars, and abstract thinkers; Xenophon, who, while yet a youth, led the shattered remains of the ten thousand from the heart of Persia, through hostile nations back into Greece, learned his art of Socrates. Dion, the liberator of Syracuse, was the pupil of Plato; and Alexander, and several of his ablest leaders, were the scholars of Aristotle. These sages possessed the power of forming men who, in the busy and bewildering sphere of public life, maintained characters in which the beautiful contends with the sublime for ascendancy. The progress of rhetorical composition kept pace with that of philosophy. The naiveté of Herodotus was succeeded by the terse weight and depth of Thucydides, and to both, succeeded the amiable repose of Xenophon. So in like manner with poetry, which under the peculiar circumstances of Athenian society assumed the dramatic form. The dark and gigantic spirit of Æschylus, invested with the knotty convolutions of his own dragon genius, was scathed by witnessing on the stage his own dramatic version of the victory over the Persians, in which he had played a soldier's part. Sophocles touched a tenderer and a deeper tone of more equable and sustained beauty; while in Euripides, the Athenian Voltaire clothed his witty sophism in the language of real poetry. The arts of sculpture and architecture went hand in hand with the rest; neither, however, were indigenous in Greece. The relics of cities older than this period, the notices of their structure in old writers, had nothing akin to the forms and statues of the age of Pericles. Their form, the very bereavement of the earlier specimens, show them importations from Egypt; and the earliest of these structures on record—the temple of Ægina—dates not long before the age of Pericles. But how idealized do the colossal—but withal heavy and grotesque structures of Egypt—become in Grecian hands. It is as if the buoyancy and elasticity of mind had been communicated to inert matter.

While mind was thus busy and productive in the works of art, science, and literature, it was not idle in public life. False and dangerous notions of the end of government, and of the means of attaining it, were entertained by most of the Athenian statesmen; but some attained juster notions, and there were with whom "the light that led astray, was light from heaven." But then the people!—were ignorant, barbarous and fickle enough at times in all conscience; but of what people cannot that be predicated? However evil they, the Athenians, may have been, they were perhaps as good as their neighbours. To those who remind us of the death of Socrates, let our answer be, the laying of the murder at the door of the real perpetrators. The voice of many, in ignorance, had clamoured for his death; but who, in knowledge, prompted that clamour? It was the

privileged class of the initiated who dreaded the danger to their power from his bold searching spirit. This is not the only instance of the treacherous hypocrisy of those, who, for their own ends, keep the people debased and ignorant, have had the wish to induce them, by malignant falsehoods, to perpetrate a crime useful to themselves, and then held up their hands in affected horror at the atrocity of which they were the mercenary accessories. Least of all let it be said, that Athens is an example of the instability of democratic institutions. Single-handed, Athens maintained a struggle against discontented and inimical colonies, and the combined might of Persia and Lacedemon. Pressed down by the hand of God rather than man, by the enfeebling effects of a fearful pestilence, she fell once, but she soon recovered. Even under the expansion of this death-struggle, after the burst of genius which adorned the opening of this era had worn itself out, as is always the case with such preternatural displays, the soul of Athens had energy enough to thunder in accents such as were never heard in another clime. The words of Demosthenes are those of a mind equal to the best of Athens' best age; he was lashed into the sublimity of despair by the consciousness that he stood alone. Talk not of the instability of democratic institutions;—the city was an important city in Greece before Sparta was founded, and was, in all but name, an independent state at the time of the first crusade;—thus enjoying a longer life than the mightiest dynasty earth has known, it is an instance of their almost indestructible vitality.

ON THE PROPERTIES OF THE CRANK,

AND THE VARIOUS SUBSTITUTES PROPOSED FOR IT IN STEAM-ENGINES.

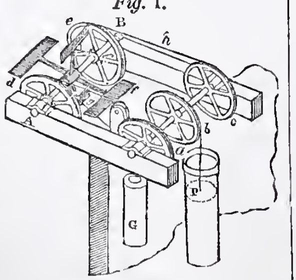
ARTICLE II.

PROPOSED SUBSTITUTES FOR THE CRANK IN STEAM-ENGINES.

In our former article on this subject, we examined the properties of the crank, and endeavoured to point out the nature of the fallacy which has called into existence a variety of contrivances for obtaining from the reciprocating motion of the steam-engine piston a rotatory effect, otherwise than by the simple crank; but, in conclusion, intimated our intention of furnishing a systematic enumeration of these fallacious schemes. This is the object of the following paper; but, considering the opinion which we have already expressed upon the question, it can hardly be supposed that we are induced to devote our space to this purpose on account of any intrinsic value which these contrivances possess. Our object is simply to place before our readers, in a connected form, the different mechanisms already proposed, and thereby to prevent, as far as our influence extends, the further wasteful expenditure of time, at least, upon the re-invention of such arrangements.

The first attempt at producing rotatory motion by mechanism, from a reciprocating piston, was made by Jonathan Hulls, in 1737. He sets forth his invention in a pamphlet published at that time, and advocates its special application to steam navigation. His mode of converting the reciprocating motion of the engine into a rotatory one, is depicted in the annexed diagram, fig. 1; in which *a, b, c,* are three wheels, on one axis; and *d, e,* two others, hung loose on a parallel axis, A, B, with ratchet wheels attached, so as to move the axis only in the forward direction. P is the piston of an atmospheric steam-engine, connected to the middle wheel, *b*, by a rope passing round the latter. *h* is another rope, connecting the wheels *c, e,* so that both must move in the same direction;

Fig. 1.

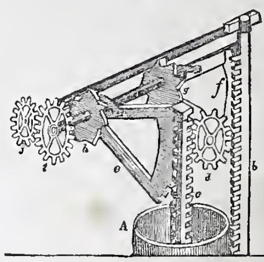


Jonathan Hulls, 1737.

and *g* is a rope which connects the wheels *a, d,* diagonally, so that they move in opposite directions. The rope *g*, proceeding from the wheel *a*, is continued round the wheel *d*, and passed over a small pulley; a weight, G, being suspended from the end of it. When the piston descends, the wheels *a, b, c,* move forward; and, by the ropes *g, h,* turn the wheels *d, e;* that is, the wheel *e* forward, and the wheel *d* backward. The paddles *f* are therefore moved round, in a forward direction, by the wheel *e;* while, at the same time, the weight G is raised by the wheel *d*. When the piston is, in the next place, ascending, the motion of the whole is reversed, except that of the paddles, which are moved in the same direction, by the action of the descending weight G upon the wheel *d*. By this alternate action, the axis A B, with the paddle-wheel, is constantly moved round in the same direction, and by an equable force.

The next in the order of time is Keane Fitzgerald, who, in 1757, described (without drawings) an invention for converting rectilineal into rotatory motion. Fig. 2 is a drawing constructed from his description. Let A be an atmospheric cylinder, and *b c* two double racks; of which, *b* works outside the cylinder, and *c* acts as piston-rod. Those double racks are each toothed on two contiguous faces; so that the pinion *d* works between one pair of racks, while the other pair give motion to two toothed sectors, *e, f,* turning on the same axis. These sectors have palls jointed to them, which fall into the teeth of the ratchet wheels *g, h*. Now, suppose the piston and the rack *c* to be ascending, then the sector *e*, catching the ratchet *h*, will turn it round, and of course the axle upon which it is placed, a portion of a revolution. When the piston has reached the top, and its motion is to be reversed, the sector *e* ceases to act; but, instead of it, the sector *f* catches the ratchet *g*, and continues the motion of the axle in the same direction. It is easy to see how the sector *f* is driven, by the intervention of the pinion *d;* and the manner in which a rotatory motion is in this way procured, and transmitted to another axle by means of the spur-wheels *i, j*. To render the motion uniform, a fly-wheel was put upon the second shaft—which is worthy of notice, as the first application of a fly-wheel to that purpose.

Fig. 2.

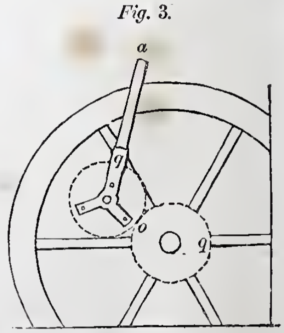


Keane Fitzgerald, 1757.

About 1768, some attempts were made by John Stewart and Dugald Clark to produce a continued rotative motion from Newcomen's engine. An atmospheric engine had been employed at Hartley colliery, to draw coals from a pit, which had a toothed sector on the end of the beam, working into a trundle; which, by means of two pinions with ratchet wheels, produced a rotative motion in the same direction, by both the ascending and descending stroke of the arc; and, by shifting the ratchets, the engine could be reversed at pleasure.

In 1781, James Watt took out his patent for the sun-and-planet motion, expressly as a substitute for the crank motion. His original intention was to adopt the simple crank motion; but he had been anticipated in his design by Matthew Washborough of Bristol, who, in the name of John Steed, obtained a patent for that motion, unknown to him, in 1778. Mr Watt, therefore, to effect his purpose, rather than contest the question, disguised the crank under the form of the sun-and-planet wheels—represented by fig. 3, and also by No. 102 in our Tables of Mechanical Movements, (Vol. I.) In this, *a* is a connecting rod, attached to the end of the beam. Upon the axis of the fly-wheel a spur-wheel is fixed, which gears with another wheel of the same diameter, and fixed to the end of the connecting rod. Suppose the connecting rod to be descending. In their existing position, the points *o* are in contact; but, when the connecting rod has descended to the lowest part of its circular course, the points *q q* will be in contact; the number

Fig. 3.

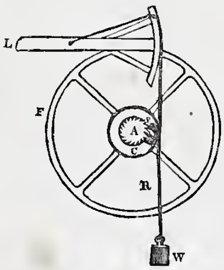


James Watt, 1781.

of teeth between o and q, in both wheels, being the same. But this cannot take place until the moveable wheel be directly under the stationary wheel on the fixed axis; and, as the piston has a full half-stroke to make till the points q q be in contact, the stationary wheel must perform a full half-revolution, whilst the other wheel describes one-fourth of its orbital movement—that is, for a full half-stroke of the piston; and, consequently, a whole revolution for every full stroke. The advantages of this motion are, that the fly-wheel makes twice the number of revolutions by this method that it would by the common crank; and thus it requires a lighter fly-wheel; besides which, it is extremely convenient where a rapid motion is necessary. There are, however, several disadvantages attending it. Among others, it is less simple, more expensive, and more liable to derangement.

In 1789, Thomas Burgess took out a patent for a mechanism adapted to convert reciprocating into rotatory motion—represented by fig. 4. Upon the axis A, to which the rotatory motion is to be communicated, a collar, C, is accurately fitted, so as to turn freely upon it; and so secured in its place, as to prevent its sliding sideways. Round the collar a chain or rope, R, is to be wound. One end of the rope is made fast to the lever, L, of a steam-engine, or other alternating moving power. To the end of the rope a weight, W, is suspended; the purpose of which is, to draw the collar back, in the interval between each stroke of the moving power. Inside of the barrel or collar C is fixed a pall, P, which falls into the notches of the axle A; so that the axle is impelled always in one direction, and is continued during the intervals of action by the fly-wheel.—This mechanism has been several times re-invented—among others, by a correspondent, A. V.

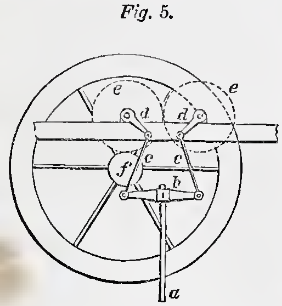
Fig. 4.



Thomas Burgess, 1789.

Edmund Cartwright obtained a patent in 1797 for a new steam-engine, in which his principal object was to procure a tight piston, and a condenser in which the steam was exposed to a large surface of water. The arrangement, for altering the rectilineal into the circular motion, requires particular notice. Fig. 5 represents this motion. a is the piston rod, on the upper end of which a cross head, b, is fixed. To the ends of this, and also to the secondary cranks d d, two links, c c, are jointed. The cranks are fixed on the axles of two toothed wheels, e e, gearing with one another; and one of which drives a pinion, f, on the shaft of the fly-wheel. Thus the speed of the fly-wheel shaft may be raised to any convenient degree, by proportioning the diameters of the wheel and pinion e, f.—This motion is figured in our Tables of Mechanical Movements, No. 69.

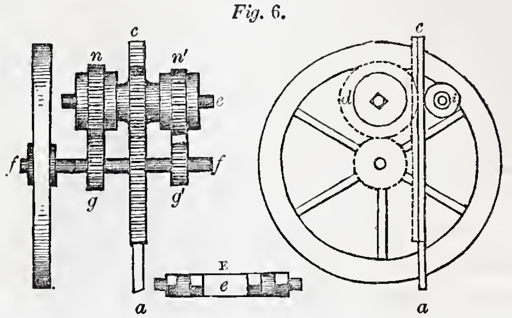
Fig. 5.



Edmund Cartwright, 1797.

Matthew Murray of Leeds, a gentleman of manufacturing celebrity, in 1799, patented a method of saving fuel, and lessening the expense of engines. The latter object he proposed to effect in the following manner:—" I cause the steam, or atmosphere, to act upon pistons moving in long pipes or cylinders, lying in a horizontal position. By this contrivance, a more convenient motion can be applied to mill work, and a much longer stroke can be obtained than in the usual way." From this alternate rectilineal motion he produces a continued rotatory motion, by the application of a single rack and pinion movement. Fig. 6 gives two views of this arrangement, showing the apparatus for one of the cylinders. a is the piston-rod continued by the rack c, which works into the socket wheel d. This wheel is hung upon an axis e, shown separately at E; the middle part e is cut into a screw, upon which the wheel d is fitted, though not fixed. Upon this axle, at both ends, three positions, are formed to receive the corresponding wheels. In the principal figure, the two toothed wheels n, n', are loose upon round bearings, and the other four plain wheels are set upon square bearings on the axis e, (see E) of which the two inner are fitted loose, and the outer ones fast upon their places. The fly-wheel shaft f f is driven in the same direction by the two toothed wheels n and n', alternately; to effect this, the wheel n drives the wheel g on the shaft f, and the wheel n' drives the wheel g' by an intermediate wheel not marked. The friction roller i supports and steadies the rack. From this arrangement it is easy to perceive that when the piston-rod moves forward, the rack turns the wheel d,

Fig. 6.



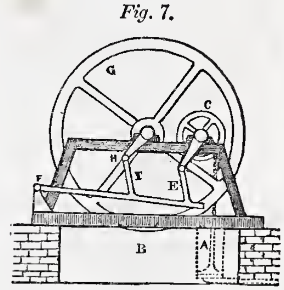
Matthew Murray, 1799.

the immediate effect of which is, that by its lateral tendency on the screwed axle e, it presses by its projecting boss upon the loose wheel or disc, which consequently presses up the wheel n against the fixed disc on the outside. Being so constrained, the wheel n goes round, and, gearing with the wheel g, drives also the fly-wheel shaft. When the piston reverses its motion, the wheel n is let loose, and the other wheel n' is wedged up in like manner against the outside disc. As it turns in the opposite direction, it acts on the wheel g' by the intermediate wheel. By this means, there is communicated to the fly-wheel shaft a constant motion in one direction.

William Lander, in 1799, and George Medhurst, in 1801, seem to have patented schemes of a similar kind as substitutes for the crank; but our information respecting them is not sufficiently precise to enable us to figure and describe them.

Fig. 7 represents the portable engine of Mr Cartwright, which he patented in 1801. A is the cylinder in which the piston works, and which is sunk into the boiler B. The piston acts upon the circumference of the pulley C, by means of a chain, which is stretched over the pulley by a counterweight. A crank on the axis of the pulley acts upon the lever F, by the connecting-rod E. At a point nearer the fulcrum, another rod I connects the lever to a shorter crank H, upon the axis of the fly-wheel G. When the pulley C is put in motion by the piston, it will, by means of its crank acting through the lever, cause the crank H also to revolve. Suppose, in the first place, that the semi-circumference of the pulley is just equal to the travel of the piston, it is clear that while the piston moves between the top and bottom of the cylinder, by the alternate action of the steam and the counterweight, the pulley C and *its* crank will be performing a semi-revolution on the same side of the centre, alternately upward and downward. And it is easy to see that while the crank, H, is likewise moved through a half revolution on the ascending side, for example, it will be carried forward by the fly-wheel, and will perform its descending course on the other side. Thus, while a reciprocating rotatory motion is communicated to the crank upon the axis of the pulley, C, the fly-wheel shaft obtains a continuous rotatory motion. Again, by diminishing the diameter of the pulley, so that it will describe a complete revolution, and back again during a double stroke

Fig. 7.

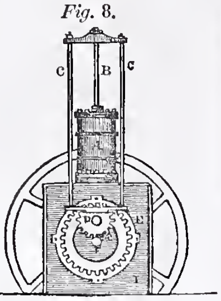


Edmund Cartwright, 1801.

of the piston, two double strokes will be given to the lever F, and consequently also the fly-wheel will make two revolutions during a double stroke of the piston. By still further reducing the size of the pulley C, with the same travel of piston, a greater number of revolutions may be communicated to the fly-wheel by each double stroke of the piston. The fly-wheel may thus be made to revolve with any required velocity without the intervention of any kind of wheel-work.

Though this engine is simple and portable, it appears to us neither so ingenious nor so elegant as Mr Cartwright's first arrangement. Both, however, were superseded by a more ingenious form of portable engine, the invention of Matthew Murray of Leeds, and for which he obtained a patent in 1802. One view of it is given in fig. 8. A, the steam cylinder; B, the piston rod; C C, two side rods connected by cross pieces for connecting the piston-rod to a pin fixed to the side of the spur-wheel D at the pitch line. This wheel works within, and is equal in diameter to the radius of an interior spur-wheel E, fixed upon the iron frame I; the plain wheel F fixed upon the fly-wheel shaft G, is furnished with a double conical pin as a centre upon which the wheel D runs. When the engine is going, the centre of this wheel is carried round with the wheel E, while at the same time, the pin in its circumference, to which the frame C C is attached, moves alternately up and down in a right line equal to the stroke of the piston. This ingenious and elegant apparatus, it will be observed, is a crank in disguise like Watt's sun-and-planet motion, and of course answers the purpose well. It was proved, indeed, to have infringed Watt's right, and in consequence the patent was repealed in 1803. It is still employed in small steam engines under the name of White's parallel motion. (See Tables of Mechanical Movements, No. 68.)

Fig. 8.



Matthew Murray, 1802.

Richard Witty of Hull, procured a patent in 1810 for an engine, upon which he afterwards made improvements; these he made the subject of a second patent in 1811. His invention consisted in making the piston draw or force round the machinery, whilst itself had a motion compounded of a rectilineal and a rotatory movement, for while it regularly traversed a straight cylinder, the cylinder itself revolved upon an axis. Two views of the arrangement are given in figs. 9 and 10. In fig. 9, A is

Fig. 9.

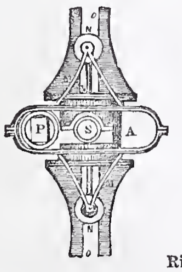
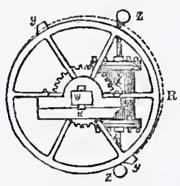


Fig 10.



Richard Witty, 1811.

the steam cylinder hung upon an axis, S, exactly at the centre. One end of this axis is made hollow to permit the access of the steam, the arrangements for which we need not describe. This the inventor calls the *cardioid* motion; it consists of a frame or trammel groove, joined to the piston-rod by the two triangles M M; the two friction-wheels N, N, are hung upon the ends of these triangles, and run upon cross-heads fixed on the ends of the piston-rod, and thus glide between the parallel slides *o o*, bolted down upon the cylinder. At the distance of half the stroke of the piston from the centre of the cylinder-shaft S, is fixed a strong stud or pin, having a strong knee at right angles, to support that shaft. The square end of this stud is driven tight into another piece of cast-iron, which is bolted down to a beam. On a round part of the stud a wheel is placed filling the trammel groove. When the steam is admitted under the piston, the trammel groove moves with the piston-rod, and is turned from a rectilinear to a rotatory direction by the stud P resisting on one side of the trammel; this causes the cylinder to turn towards the stud, and as it revolves, the groove comes into a perpendicular position, or at right angles to the position given to it in the figure. When the cylinder lies horizontally, the piston is at the extremity of the stroke, and the alternations of the steam take place at that instant in the axis. At this point the engine is passing the centres, similarly to a beam engine at the vertical position of the crank. Thus a continued revolving of the cylinder is effected, while its piston describes a circle of which the diameter is half the length of the stroke.

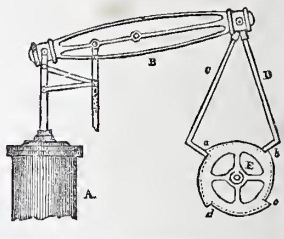
Fig. 10, is a method of applying the force of the piston upon a wheel R or crank, which revolves upon a separate axis at W, placed half the length of stroke from the centre of the cylinder-shaft X, which is supported by a knee from the centre of the wheel, similarly to the arrangement in fig. 9. The diameter of the wheel is equal to the length of the piston-rod; and has its rim made to incline or project in order that the piston rod may lay hold of it alternately at the stops *y y*. The advantages claimed for this engine are a saving of power lost by reciprocation in the ordinary engine, and dispensing with a fly-wheel. The former advantage is counterbalanced by the friction consequent on the use of a grooved frame, and the risk of breaking the piston-rod, by its oblique application of the steam power; for in no part of the revolution do the directions of the impulse and resulting motion, contain a less angle than 45°. And as there are different angles of obliquity, it is evident that a fly-wheel is as necessary in this as in the common beam engine.

In 1816, J. J. Dawes of Bromwich, patented a parallel motion, as a substitute for the crank, but we are unacquainted with its peculiarities.

In 1817, Tobias Mitchell took a patent (?) for another method, according to which a ratchet wheel, considerably larger in diameter than the stroke of the piston, was fixed upon the fly-wheel shaft; from the end of the beam hung two detents, which operated one on each side of the ratchet wheel, so that while they received the alternate motion of the piston, they would also act alternately upon the teeth of the wheel, and thus induce a continuous motion.

Figure 11, illustrates the motion just described. A, is the cylinder; B, the beam; C, D, two ratchets suspended like a connecting-rod from the end of the beam; E, a wheel of which the circumference is divided into four parts, *a*, *b*, *c*, *d*, each being a segment of an eccentric. A groove, represented by a dotted line, runs round the wheel, which guides the ends of the rods C, D. In the figure, the engine is represented at the bottom of the stroke. When the piston ascends, the rod D acts on the shoulder at *b*, and presses round the wheel, a quarter of a revolution, bringing the notch *c*, into the position of *d*, within the reach of the other rod, C, which therefore lays hold at that point, and turns the wheel another quarter round, during the descending stroke. Thus a continued rotatory motion is attained.

Fig. 11.

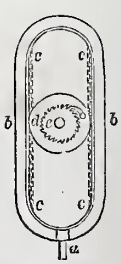


Tobias Mitchell, 1817.

Our diagram and description of this substitute are taken from a communication by W. M. N. of Wolsingham, in the county of Durham, in which he states that the motion was invented by himself—without any knowledge, we believe, of its having been before invented.

In 1820, Henry Penneck designed an engine, in which a rectangular frame was fixed to the end of the piston-rod. To the top and bottom of each side, the ends of a chain were attached, which passed over a pulley on the axis of the main shaft; these pulleys operated alternately upon ratchet-wheels, which secured the continuous motion of the fly-shaft. This motion is represented at figure 12.

Fig. 12.

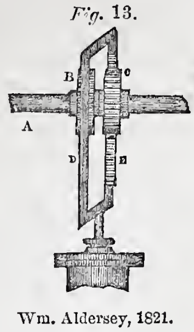


Henry Penneck, 1820.

a is the piston-rod; *b b*, the frame; and *c c*, two chains, fixed at the top and bottom of the frame, and passed once round separate pulleys, one of which, *d*, is shown. These pulleys are loose upon the main shaft, and act alternately, by means of detents, upon separate ratchet-wheels, *e*, fixed on the shaft, and thus communicate continuous motion to the shaft.

In 1821, Wm. Aldersey patented his machine, fig. 13, which consisted of a pair of racks D, E, fixed on the interior and opposite sides of an oblong frame attached to the piston-rod. These racks wrought into two spur-wheels of equal diameter, B, C, upon the main shaft A, and by driving them alternately, gave the shaft a uniform motion.

Fig. 13.



Wm. Aldersey, 1821.

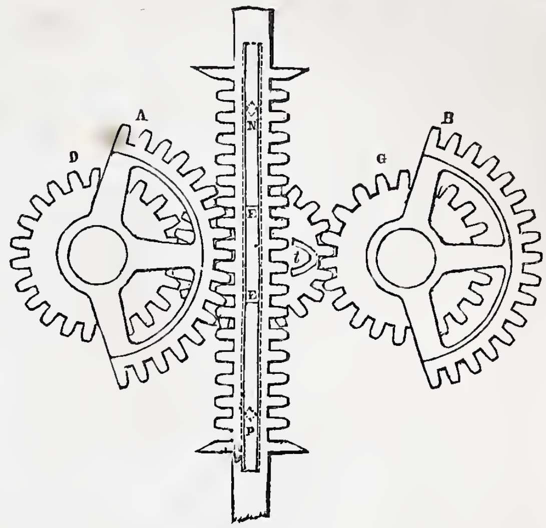
Our illustration in this instance is taken from a communication received in March last, from Robert Hindle, Jun., of Preston, who seems to have re-invented it. See Tables of Mechanical Movements, No. 67, for a motion identical in principle, though slightly different in arrangement.

In 1827, Robert Barlow of Chelsea patented a substitute for the crank, of which we have not the particulars; and, the same year, Thomas Peck, of London, took a patent for a sort of revolving steam-engine, with which we are likewise unacquainted.

In 1828, Samuel Clegg, of Liverpool, patented an engine which was intended to afford a compensation for the variation of the pressure of steam used expansively, by causing a weight to be elevated so as to produce a gradually diminishing resistance; which weight again reacts on the engine with a power gradually increased to its maximum. The vessel which the piston traverses, consists of a semi-annulus or ½-ring, the cross section of which is square, with one of its diagonals directed to the centre. This vessel is placed vertically with its two extremities in a horizontal line. The piston is attached to one end of a solid half ring, of the same cross section as the vessel, and not much smaller, which acts as a piston-rod. Its other extremity is fixed to the end of a radial arm, which proceeds from a horizontal axle, exactly concentric with the semi-annular vessel. On the radial arm are placed two or more flat weights, perforated at the centre to pass upon it. The number of these weights is regulated by the primary pressure of the steam, which they with the piston-rod are intended to compensate, as already mentioned. It is evident that when the piston is at the remote end of its stroke, the radial arm will be nearest the horizontal position, and these weights will press with most effect upon the piston. When the piston moves toward the other end, the arm rises toward the vertical position, in the progress of which motion it is clear that the weights will act with diminishing leverage, until they cease to have any effect by their pressure. Motion is communicated to a fly-wheel from the horizontal axle, by means of two other radial arms.

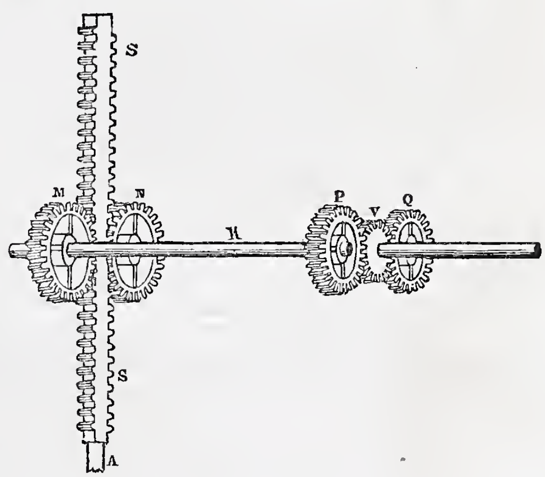
In 1836, patents for crank substitutes were secured by Wm. Lucy, and Charles Schaufhautl. The design of the latter appears to have been similar to the rack-and-pinion motions already described.

In 1839, J. G. Shuttleworth, of Manchester, patented a motion, consisting of a double rack and five wheels. The annexed figure represents Mr. Shuttleworth's movement at half-stroke of the engine. In this case there is a groove or channel in the piston-rod rack, into which works a dovetailed feather, E E, (shown with its bearing removed,) to steady it. A and B are segments of cog-wheels, on the shafts of which are fixed the wheels, D and G. These last gear with an intermediate carrier wheel, on the face of which is a tappet, *t*. This, as the piston-rod rises and carries with it the segment, A, takes a steadying pin, projecting at P, and secures the ascent of the rod sufficiently high to release the segment, A, from the rack, and to catch the segment, B. In like manner it secures the sufficient descent of the rod by the boss, N, to release the segment, B, and catch the segment, A, at the end of the down-stroke. From this arrangement it is obvious, that a continuous rotatory motion, in one direction, is given to each of the three axes—those of the segments and their corresponding wheels, and that of the intermediate wheel, and from any of these the power may be taken.



J. G. Shuttleworth, 1839.

Similar to this is the following, suggested in 1842 by an anonymous writer:—A is the end of the piston-rod; S S is a continuation of it in the form of a double rack; M, N, are two spur-wheels of equal size in gear with it. The wheels run loose on two shafts, R, R, only one of which is seen; on the other ends of these shafts are fixed two other wheels, P, Q, of equal size, between which another wheel, V, on a third shaft, works. Close to the loose wheels, M, N, a ratchet is fixed on each shaft, and detents attached to the wheels, which, being operated on by springs, catch the teeth of the ratchets alternately when the engine is going, corresponding to the alternate motion of the piston-rack. By this arrangement, the spur-wheel, V, being wrought by the other two alternately, a uniform motion is given to its shaft. It is obvious, too, that by adopting various sizes of wheels, this shaft may be made to have any number of revolutions during one double stroke of the piston.

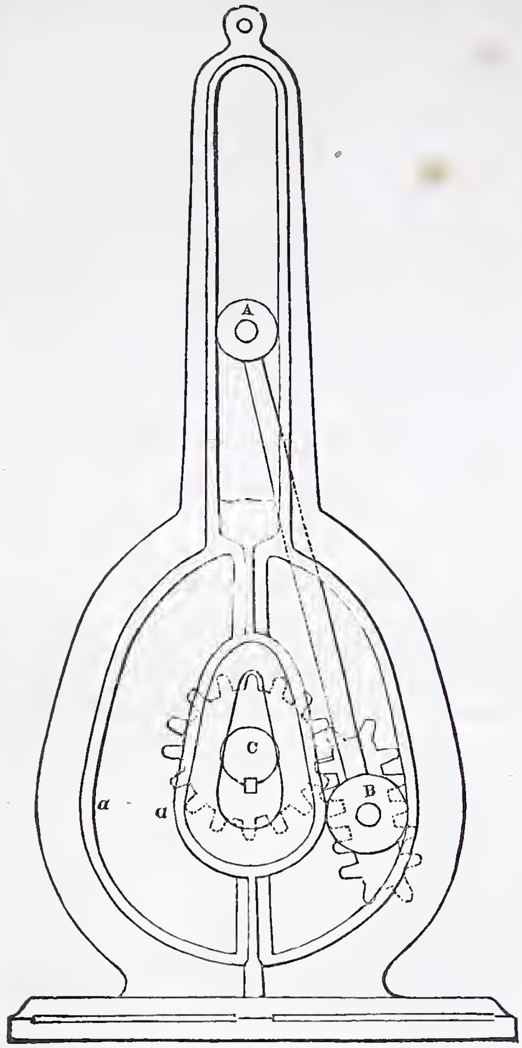


Anonymous, 1842.

In the same year, Mr. William Moir, of Liverpool, invented what he calls the "sun-and-comet motion," of which the following is a drawing:—

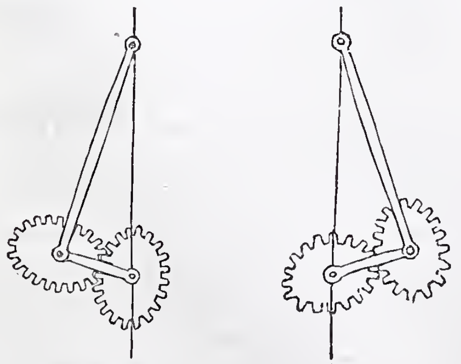
A B is the connecting-rod, jointed at A to the piston-rod, and fastened at B to an oblong double rack, which drives the spur-wheel on the crank-shaft, C. At A, a friction roller is attached to guide the piston-rod; and at B another is attached to the oblong rack, to keep it in proper contact with the wheel. This roller runs between two slide surfaces, *a*, *a*, which are carried all round. The form of these surfaces varies with the length of the connecting-rod, and the relative proportions of the double rack and wheel. The advantage which this motion appears to possess over the sun-and-planet is, that it will have less obliquity of action than the other. However, we should think that this is more than compensated in the sun-and-planet, by

the superior simplicity of the method of keeping the wheels in gear, by a link connecting their centres, which is not available in this case.



William Moir, 1842.

Subsequently, Mr. Moir proposed a "new sun-and-planet motion," of the elliptic form, the principle of which is sufficiently explained by the subjoined figures.



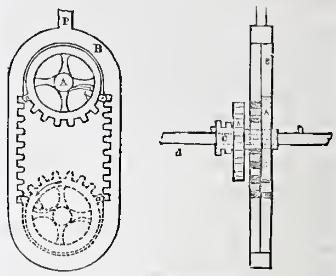
Best position. Worst position.

William Moir, 1842.

The plan, so far as it proposes simply the gearing of two elliptical wheels together, is not, of course, presumed to be new—(see Mechanical Movements, plate 3, fig. 100); but we believe the application is entirely so, and it has certainly the merit of approximating to a uniformity of crank leverage more simple than any analogous plan which we have before seen suggested. It consists of two toothed ellipses of equal dimensions, one of which is fixed on the fly-wheel shaft, and the other on the end of the connecting-rod. They are so related to one another, that, in certain positions, the transverse axis of the one touches the conjugate axis of the other; in which case, by a property of the ellipse, the distance between their centres remains constant in the course of the revolution of the one about the other. Thus their centres may be linked together, and kept steadily in gear, which cannot be done with the other motion.

In 1843, Mr. C. A. Bowdler, of Halloway, published the following motion, which he described as invented by himself four years before. It is represented by figs. 14 and 15. A partially toothed wheel is acted upon alternately by the two toothed sides of the frame, which is moved by the piston-rod. The reverse motion of the engine is effected by using two racks and wheels, as shown in figure 15, by locking in or out either of the wheels in the corresponding rack, without requiring the reverse action of the valves. The two extreme positions of the wheel are given, showing how the teeth of the wheel and the rack engage and disengage. The left side of the rack has, in descending, turned the wheel A round, and locked the spring-tooth into the right side of the rack, which secures the continued action. This motion is a re-invention by Mr Bowdler, as will be seen by reference to our table of Movements, No. 64.

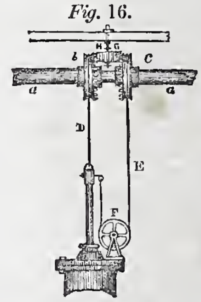
Fig. 14. *Fig.* 15.



C. A. Bowdler, 1843.

Figure 16 represents a motion by R. Hindle, jun., of Preston. *a*, *a*, represents the driving shaft of an engine; *b*, *c*, two ratchet pulleys moveable upon the shaft, with detents attached to prevent them turning in one direction without turning the shaft also; but allowing them to move in the other direction independently of it. D, a chain connected at one end to the piston-rod of a steam cylinder, at the other end to the rim of the ratchet wheel, *b*. E is a similar chain connected also to the piston-rod at one end, passing round the pulley, F, (which is to change the direction of the chain) upwards to the ratchet pulley, *c*, where it is fastened. G is a fixed stud, and H a small pinion which works upon it, and gears into the teeth on the inside of both ratchet wheels. The use of the pinion is to draw up, alternately, the ratchet wheels and chains for the next new stroke.

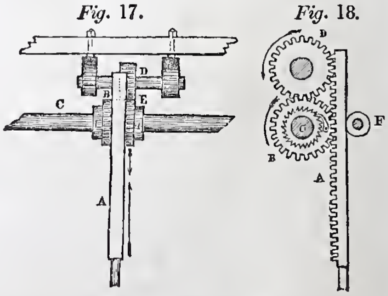
Fig. 16.



Robert Hindle, jun., 1843.

The three following schemes are by William Johnson of Preston. In that represented by figs. 17 and 18, the top of the piston-rod is continued by a toothed rack, A, which is made broad, so that one half its breadth gears into the wheel B, on the shaft C to be driven, and the other half into the wheel D, which is fast on a shaft supported on hangers fixed to a beam above. This last wheel gears into the wheel E, of the same size as B, and which is also placed

Fig. 17. *Fig.* 18.

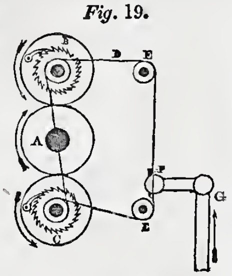


William Johnson, 1843.

upon the shaft c. Both of these wheels are furnished with detents placed in the same direction.

By attention to fig. 17, it will be seen, that if the rack is moved upward, as indicated by the arrow, it will cause the wheel B, by means of the ratchet, to turn the shaft forward; and as it also gears into D, this wheel will drive the wheel E backward, the ratchet allowing it to move loose on the shaft; upon the rack coming down again, the wheel B will turn backward, and E forward: thus in the up-stroke, B will drive the shaft, and in the down, E will do the same. F, in fig. 18, is a roller to keep the rack in contact with the wheels. In this figure the wheels B and D appear to gear with one another, but this is not the case.

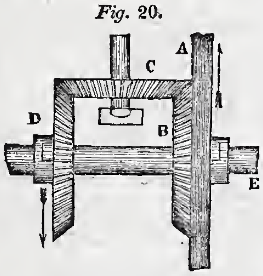
Fig. 19.



William Johnson, 1843.

Fig. 19 represents a contrivance upon the same principle, but motion is communicated to the wheels by means of a band, instead of the rack. The wheel A is fast upon the shaft to be driven; and into this the two wheels B and C gear: the teeth are not shown. G is the supposed piston-rod, which is connected at F to the strap D; this strap passes over pulleys at E E, which are merely used as guide pulleys, to allow the piston-rod to work clear of the wheels, and from thence it passes over two pulleys B and C, in contrary directions; these are connected to the two wheels by means of ratchets both set in one direction. Thus, by the reciprocal motion of the piston-rod, a continuous circular motion is given to the wheel A on the driven shaft.

Fig. 20.

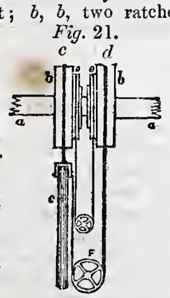


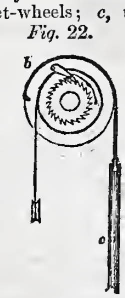
William Johnson, 1843.

In fig. 20, the piston-rod is continued by a rack A, which gears into a wheel formed in one piece with the bevel wheel B, upon the shaft E to be driven. The wheels B and D are of equal size, and number of teeth: they are free to revolve in contrary directions upon the shaft E, and being connected by the carrier wheel C, it is plain that the wheel B being made to revolve by the ascent of the piston, will cause the wheel D to turn in the opposite direction; and that the descent of the piston will reverse the motions of the wheels. But it is also plain that the one being always loose, while the other is fast upon the shaft E, that this shaft will be made uniformly to move in one direction by the reciprocating motion of the piston.

Figs. 21 and 22 represent a substitute by an anonymous inventor. Here *a a* is the main shaft; *b*, *b*, two ratchet-wheels; *c*, the piston-rod, connected by two belts, *d*, *e*, to the circumferences of these wheels, one to each wheel; one belt is reversed by a doubling pulley F; *e*, *e*, are two smaller pulleys fixed to the sides of the ratchet wheels; on these, the two ends of a belt are lapped in the opposite directions, which is passed under a doubling pulley between them. Suppose the piston to be descending, it will draw with itself the belt *c*, which causes the first wheel *b* to revolve, taking with it the shaft *a*. During the descent, it is evident that the belt *d* must be gathered in and wound over the second wheel *b*; this is accomplished by the small pulleys *e e*, and their strap.

Fig. 21. *Fig.* 22.





Anonymous.

Among this heterogenous collection, we have a few gems, like diamonds in a heap of rubbish; but it is easy to perceive, that whatever is really good, like Watt's sun-and-planet wheels, and Murray's parallel motion, that the inherent virtue is that of the simple crank. That the general failure of all such contrivances does not arise from defects of construction, or other accidental circumstances, is rendered obvious by the variety of forms under which they have been tried; and the names attached to many of them are sufficient evidence that failure was not the result of imperfect workmanship, or other technical deficiency. The defect is inherent in the very object which they were designed to accomplish; namely, to give uniform leverage to the reciprocating motion at all points of its action. But in effecting this imaginary advantage, it is essentially necessary that the parts must be instantly brought from a state of full motion to absolute rest; and must as instantaneously again be set in full motion. This is inconsistent with the circumstances of the case: matter in motion acquires momentum which must be gradually overcome, in order to bring it to rest without shock or concussion, and *vice versa.* This is beautifully provided for in the simple crank; but in the substitutes for it, with the exceptions pointed out, the provision is entirely wanting. This is the fatal defect. In consequence of it, no sufficient strength could be given to the parts, to make them bare up under the sudden reversions of motion, to which they are necessarily subjected.

BAIN'S ELECTRO-MAGNETIC INVENTIONS.

DISPUTES respecting priority of inventions are always painful, and seldom satisfactory. With reference to the subject before us, the question at issue is, whether Professor Wheatstone or Mr. Bain is the inventor of the Electro-Magnetic Printing Telegraph, and also of the Electro-Magnetic Clocks. Setting aside the *legal* rights which both parties have sought under the banner of the patent laws, the *moral* right, which is of a far higher order, unquestionably belongs to the "working mechanic," as Professor Wheatstone disparagingly designated the young stranger from Caithness. In this we include the Electro-Printing Telegraph, and Electro-Magnetic Clocks, to the merits of which we are about to direct attention; but we must take exception to the claims of both parties to the merit of being first discoverers, that an electric current can be transmitted from one distant point to another, through the ground or through water. This discovery belongs to Professor Steinheil of Munich, and is detailed in his paper upon "Telegraphic Communication by means of Galvanism," a translation of which, by Julian Guggsworth, may be found in Sturgeon's *Annals of Electricity, Vol. III., pp.* 439 and 509, published in March and April, 1839. From this paper we quote the following remarks. Alluding to the number of conducting wires required in the different electric telegraphs proposed, he says—

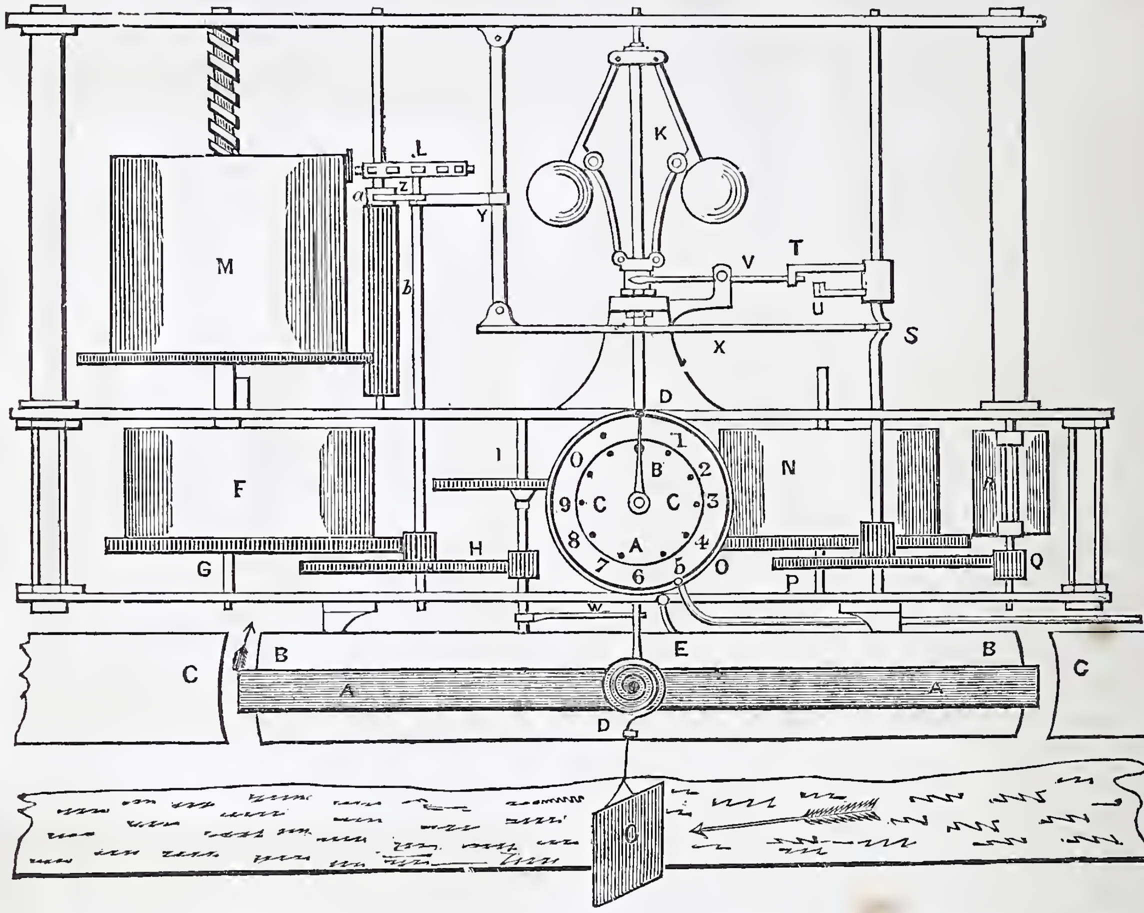
"Ampère required more than sixty wires, whereas thirty were sufficient for Sommering. Wheatstone and Cooke reduced their number to five; Gauss, and, probably in imitation of him, Schilling, as likewise Morse in New York, made use of but a single wire, running to the distant station and back. One might imagine that this part of the arrangement could not be further simplified; such, however, is by no means the case. I have found that even the half of this length of wire may be dispensed with, and that, with certain precautions, its place is supplied by the ground itself. We know in theory that the conducting powers of the ground and of water are very small compared with that of the metals, especially copper. It seems, however, to have been previously overlooked that we have it within our reach to make a perfectly good conductor out of water, or any other of the so-called semi-conductors. All that is required is, that the surface that its section presents should be as much greater than that of the metal as its conducting power is less. In that case the resistance offered by the semi-conductor will equal that of the perfect conductor; and as we can make conductors of the ground of any size we please, simply by adapting, to the ends of the wires, plates presenting a sufficient surface of contact, it is evident that we can diminish the resistance offered by the ground or by water to any extent we like. We can indeed so reduce this resistance as to make it quite insensible when compared to that offered by the metallic circuit, so that not only is half the wire spared, but even the resistance that such a circuit would present is diminished by one-half. This fact, the importance of which in the erection of galvanic telegraphs speaks for itself, furnishes us with another additional feature in which galvanism resembles electricity. The experiments of Winkler, at Leipzig, had already shown us that, with frictional electricity, the ground may replace a portion of the discharging wire. The same is now known to hold good with respect to galvanic currents."

This statement places the question of priority beyond dispute. Although, however, in justice to Steinheil, we cannot allow Mr. Alexander Bain's claim to the merit of being the first discoverer of

the conducting power of the ground, we readily admit, in its fullest extent, the great ingenuity displayed in the following electro-magnetic arrangements, and the service which he has rendered to that department of applied science to which they belong.

I.—The Electro-Magnetic Printing Telegraph.

The annexed drawing represents one part of this apparatus complete in all its details; and if we imagine an exact counterpart of that shown to be placed at the distant station to which it is to communicate, and connected in a galvanic circuit, of which the ground forms one-half, our conception of the arrangement is complete. The machines being thus in every respect alike, the same letters of reference may also be supposed to denote the same parts in each; and that every effect produced in the one will be reproduced by communication in the other. A, in the drawing given below, denotes the signal dial, which is insulated from the machine; B, the hand or pointer; and C C, holes in the dial, one under each signal. D is a similar hole over the starting-point of the handle, B. At the bottom of the machine is a coil of wire marked A A, upon a light hollow frame of wood, and freely suspended and moveable upon a centre; within this coil is a powerful permanent magnet, B B, immoveably fixed upon the frame of this machine; and C C are the ends of similar magnets. D is one of a pair of spiral springs connected with the source of electricity, and which convey the electric current to the wire-coil, and, at the same time, leave the coil free to move



in obedience to the magnetic influence. E is an arm fixed to, and carried by, the wire-coil, and which catches against the stop-lever W, which communicates with the mainspring barrel F by the train H, G. By means of this train, and the wheel I—the stop E being removed from its bearing—the action of the mainspring barrel F is transmitted to the hand B of the dial, and to the governor K. On the top of the arbor of the wheel H is fixed the type-wheel L, at a convenient distance from the cylinder M, on which the paper for receiving the printed communications is fixed. N is a second mainspring barrel, with its train of wheels O, P, Q, and fly or vane R. On the arbor of the wheel P is a crank at S, and two pallets T, U, which prevent the wheels from revolving by contact with the lever V. The crank-rod X is connected with the spindle Y, on which is an arm connecting it with the upright shaft which carries the type-wheel L. On the same arm is a spring Z, which presses against the periphery of the ratchet-wheel *a*, fast upon the axis of the long pinion *b*, which gears into the wheel upon the under end of the paper cylinder M. The axis of the cylinder M is fixed, and has a thread cut upon it to suit a corresponding internal thread in the cylinder. By this adjustment, the cylinder, on being made to revolve, will at the same time be elevated or depressed, according to the direction of the motion.

When the telegraph is not at work, a current of electricity is constantly passing from the *zinc* plate placed in the ground at the distant station, through the water or moisture of the earth intervening, to the copper plate C at the station, where our drawing is supposed to be made. From the copper the galvanic current passes up through the freely suspended multiplying coil A A, which it deflects, into the machinery, and thence to the dial by means of a metal pin inserted in the hole D; from the dial it passes by a single insulated conducting-wire back to the zinc plate where it started, traversing in its course the machine at the distant station and *its* multiplying coil, which it also of course deflects. The circuit is thus complete.

When a communication is to be transmitted from one station to the other, the attendant withdraws the metal pin from the hole D in the dial of his machine: the current is thus broken, and the ends of the multiplying coils A A, at both stations, are carried upward in the direction of the arrow by the force of the spiral springs. The stops E, attached to the coils, moving to the right, release the levers W, leaving the

wheel-work of the machinery thereby free to revolve; and as the moving and regulating powers are the same at both stations, the machines go accurately together; that is, the hands of both machines pass over similar signals at the same instant of time, and corresponding types are continually brought opposite to the printing cylinders at the same moment. By the motion of the trains, the balls of the governor K, after several revolutions, are made to diverge in obedience to the centrifugal force which they acquire; one end of the lever V is thereby raised, and the other depressed out of contact with the pallet T, into contact with the second pallet U. The operator having inserted the metal pin in the hole under the signal which he wishes to communicate, the moment the hand of the dial comes into contact with it, the circuit is again completed, and both machines stop instantly. The governor-balls collapsing raise the left hand end of the lever V out of contact with the pallet *u*; this allows the crank-shaft S to make one revolution before it is caught by the pallet T. The motion of the crank, by means of the crank-rod X acting upon the lever Y, presses the type of the type-wheel L, corresponding to the signal on the dial, against the paper cylinder M, leaving its impress upon the paper; at the same time the spring Z, upon the arm of the lever Y, takes into a tooth of the small ratchet-wheel *a*, and turns the long pinion *b* through a corresponding space, and consequently the cylinder wheel with which it gears. By this means a fresh surface is presented to the action of the next type that is to be impressed; and, as the cylinder has a spiral motion by which it is gradually raised to receive the successive lines, the communication is printed in a continuous spiral line until the paper is filled.

In order that the letters printed by the apparatus may be distinct and legible, two thicknesses of ribband, saturated with printing ink and dried, are supported by two rollers (not shown) so as to interpose between the type-wheel and cylinder. If a second copy of the message—which, it must be observed, is simultaneously printed at both stations—be desired at either, a slip of white paper is placed between the ribands to receive the imprint at the same time as the cylinder. The signals, it may be remarked, may either be symbols agreed upon, and reduced to a code, such as those employed with Messrs Cooke and Wheatstone's electric telegraph, or the communication may be transmitted in words at full length. The former will, doubtlessly, on account of its facility, be the mode adopted on all ordinary occasions, and where it is applicable; but in cases of an unusual nature, where the intelligence is of a kind not embraced in the code, the arrangement admits of ready extension to meet the exigencies of the case.

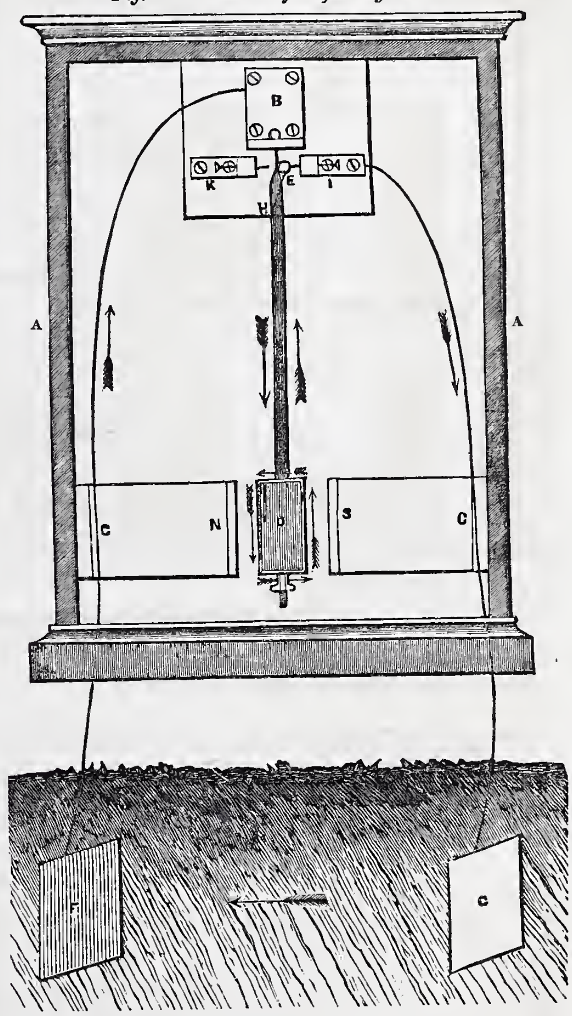
This apparatus may possibly be susceptible of further simplification; but, taking it in its present state, it is undoubtedly capable of very extensive application, not only on lines of railway, but also as a means of general communication between all the principal centres throughout the kingdom. We can, indeed, suppose it to be within the range of probable advancement, that the electro-magnetic printing telegraph shall become as extensively known and applied, and be considered as necessary in our national economy as our established system of postage is at present.

II.—Electro-Magnetic Clock.

In the first arrangement by which Mr Bain proposed to work a number of clocks simultaneously, the clocks being all included in the same galvanic current, the pendulum of the prime mover carried near its upper end a light brass spring which acted upon a plate of ivory fixed to the frame of the clock, and having a slip of brass inserted in it, in connexion with the positive pole of the battery. By this contrivance, every vibration of the pendulum, by causing the spring upon it to pass over the slip of brass in the ivory plate, completed the circuit, the pendulum itself being in constant connexion with the negative pole of the battery. This arrangement has, however, of late undergone very material practical improvement, by which a less powerful electric current is competent to the same effect. The annexed diagram represents the latest modification of the regulating pendulum, which is moved by a terrestrial battery of not more than five feet of surface.

Description.—A A is a mahogany case with a glass front; B is a metal bracket fixed to the back of the case, and to which the pendulum D is suspended. C C are permanent steel magnets fixed to the sides of the case, in such a manner as that the pendulum-ball D can vibrate freely between the poles of each magnet. The magnets are so placed as that poles of dissimilar names face each other. E is a small platinum ball affixed to a brass stem, free to move to one side or the other, being fastened to a light spindle carried by the pendulum-rod at H. The plate of copper F is deposited in the moist earth, from which a wire leads to the bracket B. The plate of zinc G is likewise deposited in the earth, and its wire leads to the piece of metal I. To the lower end of the suspension-spring of the pendulum is attached a wire coated with silk. It is led down the back of the rod (which is wood), and then coiled longitudinally, in many convolutions, around the edge of the pendulum-ball, in a groove previously made for the purpose. It is then taken up the back of the rod, and terminates in the bearings of the spindle at H. The

Fig. 1.—*Pendulum of Regulating Clock.*

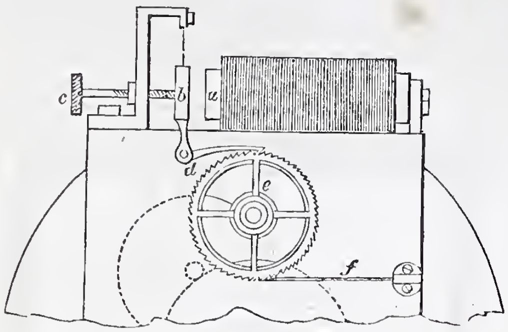


action of the apparatus may be thus explained:—A constant and uniform current of electricity would be established and would pass through the earth, the plates and wires in the direction of the arrows, as long as the platinum ball E rests on the platinum pin projecting from the metal I. But if the pendulum is put in motion, suppose that, at first, it were drawn aside until the ball D should be between the poles of the right-hand magnet, the point H being now farther to the right than the ball E, the latter would fall to the left and rest on the pin K, until the pendulum took its vibration to the left, when the ball E would fall to the right, and so on continually, the action being produced by the change of the centre of gravitation at each vibration of the pendulum. This action of the ball E lets on and cuts off the

flow of electricity at or near the extreme ends of the pendulum's vibrations, so that the convolving wire of the pendulum-ball is attracted and repelled by the magnets at the proper points of its vibrations, and thus a continual motion is kept up for an indefinite period of time.

Mr Bain has contrived two modes of working the secondary clocks by means of the prime mover described. The first in order of time is that depicted in the subjoined diagram, fig. 2,

Fig. 2.



which shows the back of the clock. In this, *a* is an electro-magnet, and *b*, its feeder, suspended by a spring, pendulum fashion; *c* is a small screw to regulate the distance of the feeder from the electro-magnet. At the lower end of the feeder is jointed a light click-lever, *d*, which takes into the teeth of the ratchet-wheel *e*. Bearing upon the under side of the ratchet-wheel *e*, is a spring, *f*, which keeps it steady.

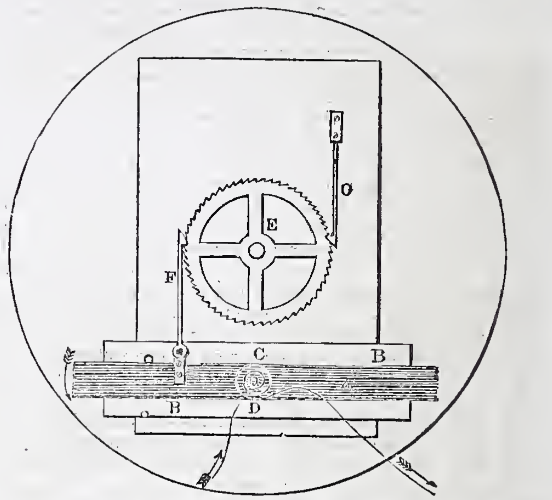
When the pendulum of the primary clock sends an electric current through the conducting wire, the feeder is attracted by the magnet, and the click-lever *d* takes over one tooth of the ratchet-wheel; upon the current being arrested, the feeder falls back into its former position, and causes the click-lever to draw the ratchet-wheel one tooth forward. The arbor of the ratchet-wheel carries the *second's hand*, which is thus taken forward one degree every second, corresponding to the vibration of the pendulum of the regulating clock. A pinion on the ratchet-arbor gives motion to the wheelwork of the minute and hour hands.

By this arrangement, it is necessary to increase the power of the electric current in the ratio of the number of clocks to be kept in motion. To avoid this practical difficulty, Mr Bain proposes to work the clocks when the number is great, not simultaneously, but in rotation. For this purpose, the ratchet-wheel *e* is placed on the arbor of the *minute-hand*, and is moved every minute instead of every second in the following manner: Upon the face of the regulating clock is fixed an ivory circle with slips or studs of metal inserted into it flush with its surface, and corresponding in number with the number of clocks to be worked. In the centre of this circle is placed the arbor of the second's hand of the clock, upon which is fixed a slight metal spring with its free end in contact with the ivory circle. The conducting wire in connexion with the positive pole of the battery is in connexion with the frame-work of the clock; every time therefore that the second's hand passes over a metal stud in the ivory circle, an electric circuit is completed, and a current transmitted to the clock, or group of clocks, in connexion with that stud; and as the second's hand passes over every portion of the circle once in each minute, the whole number of clocks thus connected with the regulating clock will be moved forward one degree during such revolution; that is, every minute of time. By this arrangement a large amount of electric power is saved, since the current has only to act on a single clock, or small group of clocks, at the same instant.

Fig. 3, shows a method adopted by Mr Bain for working the electric clock by the deflection of the wire coil, instead of the electro-magnet. A is a coil of insulated copper wire, freely suspended on centres as in the electro-magnetic telegraph; B is a compound permanent steel magnet immovably fixed within the coil; e is one of two spiral springs (one on each side of the coil) for the purpose of conveying the electric current from the stationary conducting wire D, to the moveable coil. F is a click-lever attached to the coil; E a ratchet-wheel fixed upon the minute-hand-arbor of the clock, and G, a spring click to keep the wheel steady. The regulating clock transmits the electric current to the wire coil, upon which the left hand end is instantly depressed, and the click-lever F draws the wheel E forward one tooth. When the flow of electricity from the regulating clock is arrested, the wire coil resumes its original horizontal position by the action of the springs e. If the clock receives an electric current once every second, the wheel E is placed upon the arbor of the second's hand; but if the electricity is only transmitted once every minute, then the wheel E must be placed on the arbor of the minute hand.

By these means, the time at any particular place may be

Fig. 3.



shown at any moderate distance with the utmost exactness. It is not indeed too much to expect, that in the progress of improvement, every city and town, *as a matter of economy*, will have its central clock, from which *time* will be supplied to every house, from its centre to its most distant suburb, in the same manner as water and gas are at present furnished. This is not a chimerical idea; it is beyond doubt practical, and after the first cost of the distribution, the whole sustaining expense would be trifling indeed compared with the convenience afforded.

III.—The Voltaic Governor.

This apparatus has been designated a voltaic *governor*, from its power of controlling the electric force, as the governor of a steam-engine controls the supply of steam to the piston. In all forms of the constant battery, it is well known that the energy of the action declines in proportion as it is continued; and that though for many practical purposes the action may be assumed *constant*, and employed as such, yet it is in truth a diminishing action, which requires continual revival for continued operations. The common means of securing a comparative constancy of action, for a lengthened period of time, is by surcharging the exciting liquid with sulphate of copper, so that the exhaustion consequent on continued action may be recruited as it occurs. In this, as in all previous modes of adjusting the action to the work to be done, the sources of adjustment are entirely chemical. The mode adopted by Mr Bain is different; and in this the novelty of his contrivance consists, that he employs mechanical power in conjunction with chemical affinities, —causing the two forces to counterbalance each other, and produce an aggregate equilibrium of constant action of given power.

One form of the apparatus is shown in the annexed diagram, fig. 4. In this, A A, is a wooden frame supporting the clock mechanism L, and containing in this case, two cells B B, of a Smee's battery. e c, are the zinc and platinized plates fixed to the wooden bar D D, and in proper electric connexion. M and N are binding screws attached to the respective metals of the battery. F, is an electro-magnet, and G, its keeper. By attaching

the wires, I E, the electric current passes round the magnet, and it is obvious that a given intensity of electric action will always produce in it a magnetic power to attract the keeper from a given distance; and conversely, the distance between the magnet and its keeper being given, the same amount of electric action must be exercised on the soft iron core, when the keeper is attracted from the said given distance. This being premised, the manner of using the instrument, and its mode of action may be thus explained. By means of an adjusting screw, the electro-magnet is moved till the index appended to it points to any given degree of the scale S; the frame D D, with its attached plates, is liberated and allowed to sink into the acid solution contained in the cells. But this frame being suspended to the

Fig. 4.

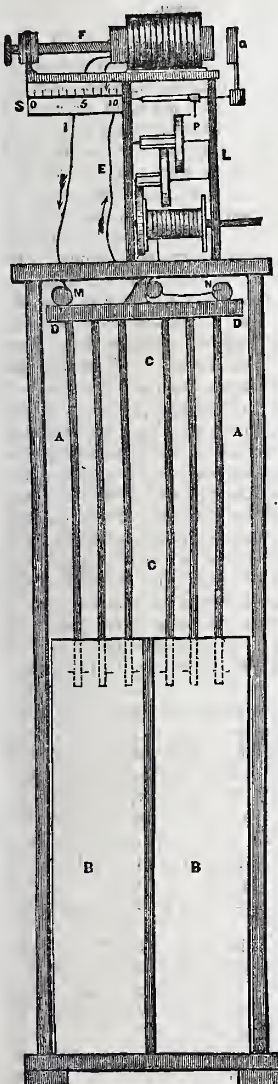
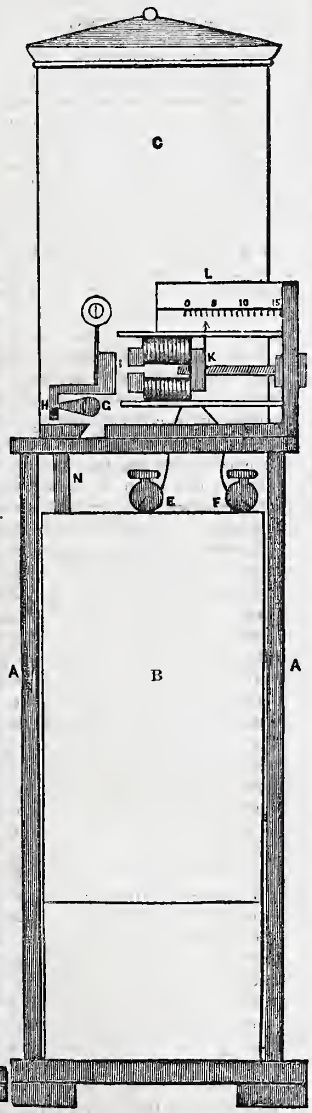


Fig. 5.



clock mechanism, to which it acts as the weight or motive power, its freedom to descend lasts only as long as the wheels are free to move. As the plates become gradually immersed in the acidulated solution, the energy of the current increases; and when it reaches the given standard marked by the index, the keeper G is attracted to the magnet. But the arbor of the keeper carries a pin which, by the backward motion of the keeper, comes into contact with the pin, *p*, projecting from one of the wheels, and thus stops the motion, and, consequently, the further descent of the plates. When the action of the exciting solution upon the plates is reduced to an extent sufficient sensibly to diminish the electro-motive power of the system, the keeper is liberated from the magnet, and by the force of a light spring returns to its original position. The plates now continue their descent in the solution, till the action is again exalted to the given standard, when the keeper returns to the magnet, and the descent is a second time stopped. In this way, the electric current is from time to time adjusted, and thereby kept within a degree on each side of the requisite strength, until metallic surface is brought into contact with the liquid in the cells.

Fig. 5 shows another arrangement of the voltaic governor. B is a cell of a Daniell's battery placed within the frame A A. It consists first of an outer cylinder of zinc, to which are attached several shelves supporting pieces of sal-ammoniac. The shelves extend above each other, from the top to the bottom of the cylinder. Within the cylinder of zinc is a porous cylinder containing a rod of copper, on which slide several copper discs, each furnished with projecting pins pointing upward, so that the discs are kept above each other at a proper distance apart. The copper is connected with the binding screw E; the zinc with the similar screw F; and these screws are respectively connected with the electro-magnet K. On commencing operations, water is poured into the battery as high as the level of the first copper disc: the copper rod having one disc attached to its lower end, is placed in the porous cell; powdered sulphate of copper is placed on the disc to the level of the pins; another disc is now slid on, and sulphate of copper is in turn placed upon it, and so on till the discs are all on the rod, and all supporting their appropriate quantity of the copper salt. The water for exciting the battery is contained in a cistern C, from which, on opening a stop-cock, it flows into the cell by the pipe G. The distance between the keeper I, and the electro-magnet K, being adjusted, as with the former instrument, (fig. 4,) the stop-cock is opened, and the water flows into the battery, until the intensity of the magnetic action is sufficient to attract the keeper when the pipe G is closed by the stopper H, and the flow of the liquid ceases, to be again renewed when the action is so far reduced as to allow the keeper to separate from the magnet.

Mr C. V. Walker observes with regard to this instrument, that "we are not in possession of any data illustrative of its action, but it appears far less efficient than the other, because the maximum action is not obtained by the mere *contact* of water with the metallic salts, but by its becoming *saturated* with them; so that the action would become much exalted *after* the keeper was in contact."

ON THE ELECTRICITY OF STEAM.

It is now more than a century since electricians discovered that electricity is generated by or during the evaporation of water. Volta demonstrated the fact by throwing water into a heated crucible, or upon burning coals contained in a chafingdish. At the instant of evaporation, or the sudden commencement of ebullition, electricity is developed, the steam exhibiting the positive, and the containing vessel the negative state. This may be considered as the sum of our knowledge of the electricity of steam, until several years ago; since which time the subject has undergone considerable investigation, and many new and interesting facts have been made known. Still, however, there is much obscurity to be cleared up, and many facts yet to be elucidated. As far as experimental inquiry has gone, there is good reason to suppose that the electricity manifested in a jet of steam is, like the electric spark from the Leyden jar, but a small indication of some great operation going on in nature, the explanation of which is reserved for future inquiry. Speculation has already been busy in explaining, from the scanty stock of facts at present known, the accumulation of electricity in the atmosphere, and other attendant metereological phenomena. It were rash, however, to hazard much conjecture on the subject until additional discoveries afford a surer guide.

The subject was revived by Professor Faraday, in a Lecture delivered by him some years ago at the Royal Institution, in which several new facts were brought forward, and previous errors corrected.

Before touching upon this Lecture, however, it will be proper briefly to survey the progress of discovery in this branch of electrical science.*

Mr. H. G. Armstrong, of Newcastle, in a letter to Professor Faraday on this important subject, relates some curious electrical phenomena observed on a boiler at Seghill, near Newcastle. The boiler was of the common construction, and had a small cylinder bolted down upon its top, on the summit of which was placed the safety valve. Between the boiler and the flange of the cylinder, a cement of chalk, oil, and tow, was interposed to render the joining steam tight. "About three weeks ago," writes Mr Armstrong, "the steam began to escape at the joining through a fissure in the cement, and has ever since continued to issue from the aperture in a copious horizontal jet. Soon after this took place, the engineman, having one of his hands immersed in the issuing steam, presented the other to the lever of the valve, with the view of adjusting the weight, when he was greatly surprised by the appearance of a brilliant spark which passed between the lever and his hand, and was accompanied by a violent wrench in his arm, wholly unlike what he had ever experienced before. The same effect was repeated when he attempted to touch any part of the boiler, or any iron work connected with it, provided his other hand was exposed to the steam. He next found, that while he held one hand in the jet of steam, he communicated a shock to every person whom he touched with the other, whether such person was in contact with the boiler, or merely standing on the brick work which supports it; but that a person touching the boiler received a much stronger shock than one who merely stood on the bricks."

We have next a paper, by Mr. H. L. Pattinson, F.G.S., on the same subject, which is published in the *Philosophical Magazine.* After describing the above effects, observed by the engineer, he gives the following as the result of his own observation :—

"1. On touching the boiler with the blunt point of a penknife anywhere about the circular end, the weight or the safety-valve itself, with the steam strongly blowing out of the joint, but with no part of the person exposed to the volume of steam, no spark could be perceived whatever.

"2. On immersing one hand in the current of steam, and touching the parts of the boiler already named with the point of a penknife held in the other, a very minute but distinct spark was perceived, and this occurred equally on all parts of the boiler, or safety-valve, within reach.

"3. By standing in the current of steam, so as to allow it to blow forcibly upon the person, the spark became larger; it was then one-eighth of an inch long.

"4. On holding a large shovel in the current of steam with one hand, and touching the boiler with a penknife held in the other, a spark was obtained three-eighths of an inch long.

"5. The cap of a gold-leaf electrometer, the bottom of which was held in the hand, was applied to the weight, the body of the operator being entirely out of the current of steam; and no divergence was produced whatever.

"6. The electrometer held in the hand had its cap applied to the weight, the other hand of the operator being immersed in the current of steam: strong divergence was immediately produced.

"From this it was evident that the electricity proceeded from the steam; but as the boiler-house was damp, so that insulation by glass could not well be preserved, a copper wire was attached to the shovel already mentioned, the end of which wire terminated in the engine-house, some yards distant from the boiler-house, where was placed a table. The shovel was held by Mr Smith in the current of steam, with its edge about an inch and a half from the aperture through which the steam issued, and the wire leading away from the shovel was insulated by being attached to sticks of sealing-wax held by assistants. Mr. Smith stood on an insulating stool.

"7. On touching a pith-ball electrometer, the threads of which were five inches long, with the insulated wire leading from the shovel held as mentioned, the balls diverged four inches with positive electricity.

"8. The wire was attached to an insulated tin conductor, when it yielded sparks half an inch in length.

"9. A pointed wire attached to this conductor exhibited the brush of light a quarter of an inch long, which always attends the escape of positive electricity from a point into the air.

"10. A small jar was now charged so strongly as to give a rather disagreeable shock. By this time a large crowd of men, women and boys from the 'Pit Raw,' or pitmen's residences near the colliery, attracted by the novelty and singularity of the circumstances, had gathered about us, filling the engine-house and looking on with great curiosity and interest. A circle of sixteen of these men and women was formed, and they received together, much to their surprise and merriment, a powerful shock from the charged jar. This was several times repeated, the numbers receiving the shock varying each time from twelve to twenty.

"11. A stout card was perforated by a discharge of the jar, and cotton wrapped round the end of a copper wire and dipped in pounded resin, readily set on fire.

"12. When the edge of the shovel was made to approach the aperture through which the steam issued as near as three quarters of an inch, very vivid and bright sparks of that length passed continually between it and the boiler.

"13. The second boiler did not discharge steam through any fissure; but on lifting its valve by the hand it blew off in a strong current. When the shovel was held in one hand in this current of steam issuing from the safety-valve, and the boiler was touched with a penknife held in the other, a spark passed exactly as under the same circumstances in the boiler subjected to the above experiments.

"From this it would appear that the steam of both boilers was in the same electrical condition.

"During the whole of these experiments the engine was doing its work as usual, occasionally going and occasionally standing; but no difference was observed in the electricity given off by the steam.

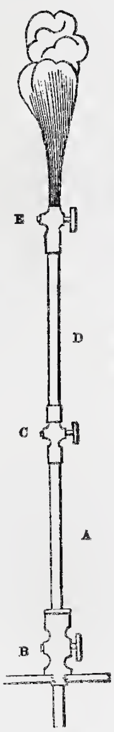
Some days afterwards, Mr. Armstrong again visited the boiler with such apparatus as he thought necessary to facilitate his experiments. When standing on an insulating stool, the intensity of the sparks between the boiler and his hand, as well as the sensation on the knuckles and wrist, were greatly increased. A brass plate, to which was attached a copper wire terminated by a brass knob, was held in the steam by means of an insulating handle. When the knob was brought within a quarter of an inch of the boiler, about sixty or seventy sparks passed between them in a minute; and when the knob was advanced about $\frac{1}{16}$th nearer the boiler, the stream of electricity was continuous. The greatest length of spark which could be obtained was fully an inch. A Florence flask coated with brass filings was charged from the knob until it discharged itself spontaneously through the glass; and several robust men received a severe shock from a small Leyden jar charged by the same means. "The strength of the sparks was quite as great, when the knob was presented to any conductor communicating with the ground, as when it was held to the boiler. It appeared to make very little difference in what part of the jet the plate attached to the conducting wire was held; but when a thick iron wire was substituted for the plate, the effect was greatest when the wire was held very near the orifice." It was observed that the intensity of the electricity fluctuated with the pressure of the steam,—the higher the pressure the more intense the sparks, and *vice versâ ;* and it was satisfactorily ascertained that the electricity of the steam was positive. The presence of electricity was also discovered in several other small streams of steam escaping from cracks or openings in the boiler; but the gold-leaf electrometer, applied to various parts of the boiler itself (which was in metallic connexion with the ground), gave no indication of electricity. Another boiler, lying adjacent to the one first experimented on, was tried with similar results. The safety-valve of this second boiler was lifted, and the steam found to be as highly electrical as the jet issuing through the crack in the boiler first tried. The two boilers—and a third which was also experimented on, when the same phenomena were observed—were supplied with water pumped out of a coal pit; the water deposited a crust of sulphate of lime mixed with a little oxide of iron and insoluble clayey matter. Another boiler supplied with rain water was tried unsuccessfully. In this case, the jet of steam was supplied by the upper gauge cock.

The next paper, in order of time, is by Mr Armstrong, dated in the following month. Between this date and his previous communication, he had tested several boilers carrying different pressures, and supplied with water of various qualities. By insulating himself, and holding a conducting-rod into the steam escaping from the safety valve, he succeeded, in every instance, in obtaining electrical sparks of from one-fourth to half an inch in length. He tried, with equal success, the locomotive boilers used on the Newcastle and North Shields Railway; and was induced to commence a series of experiments, to ascertain, first, the extent of the electricity; and secondly, the cause of the electrical development. When standing on an insulating stool, and holding an iron conducting-rod immediately above the safety valve, and bringing the other hand near a conducting body, sparks were obtained of about half an inch long, and by elevating the rod farther above the valve, the length of the sparks increased until the rod being raised about five or six feet above the valve, sparks were obtained two inches long. Small sparks

* The most of the original papers upon this subject may be found in various Numbers of the *Philosophical Magazine.*

were obtained when the rod was held in the atmosphere, two or three feet from the jet of steam; and even when the rod was held in the volume of steam floating at the roof of the shed under which the experiments were conducted, sparks were drawn down as by an electrical conductor from a thundercloud; while the person insulated felt a sprinkling of moisture on the face and hands. The electricity obtained from the steam was positive. After experimenting with various conductors, a bunch of pointed wires of different lengths was attached to one end of the iron rod, the other being terminated by a knob. The rod was held with the wires pointing downward in the jet of steam, and sparks of four inches were drawn from the knob, almost as rapidly as they could be counted; while, at the same time, a stream of electricity was passing off from that part of the rod which was nearest the funnel of the engine. Perceptible sparks were obtained when the points were held in a clear atmosphere, eight feet from the nearest part of the jet. When the valve was suddenly lifted, and the shed dark, the edges of the lever, and the margin of the brass cap which surrounded the valve became luminous;—most distinct at the instant the valve was lifted, but becoming very faint after the lapse of a second.

The question here naturally presented itself.—How or where does the steam become electrified? and to the investigation of this point Mr Armstrong subsequently directed his inquiry. The following is a description of the apparatus and experiments in his own words:—



"A is a glass tube passing into the steam chamber through the cock B, which was screwed into a hole in the top of the boiler, and was furnished with a stuffing-box to prevent escape between the outside of the tube and inner surface of the cock; C is a stop-cock affixed to the upper end of the glass tube, and upon which cock is screwed a second glass tube D terminating in another stop-cock E.

"The application of this apparatus will be easily understood. If the steam were in the same state of electricity in the boiler as when it issued into the air, it would necessarily communicate positive electricity to the insulated cock C, in passing through the tube. Or, if the steam acquired its electricity by friction, or otherwise, in the channel through which it was discharged, it could only, in the present instance, do so *at the expense* of the cock C, which, being insulated, would in that case indicate negative electricity. Or, lastly, if the electricity were developed by condensation, expansion, or any other cause which came into operation after the steam escaped into the air, then the cock C would have neither positive nor negative electricity.

"Previously to inserting the lower glass tube in the boiler, the steam was allowed to blow off through the large cock B, and the jet which issued from it proved, to the surprise of every one present, almost destitute of electricity. This result completely vitiated the inference I had drawn from the circumstance of not finding electricity in the steam from the rain-water boiler before alluded to, in which case, as I have already stated in my second letter to Professor Faraday, the jet was obtained from the gauge cock.

"The lower glass tube, without the upper one attached to it, was then passed into the boiler, and a highly electrical jet was obtained from it, which communicated positive electricity to the stop-cock C, from which the steam was discharged. The upper tube was accidentally broken in screwing it on to the lower one, leaving only about three inches of glass above the cock C. Under these circumstances the cock C still continued highly charged with positive electricity, and a pale lambent light flashed at short intervals down the inside of the tube from the cock towards the boiler.

"Having replaced the broken glass tube with a new one, the experiment was tried again on a subsequent evening, and the jet being now removed to a much greater distance than before, from the cock C, no electricity whatever could be detected in that cock, while the one above it indicated positive electricity in a very high degree. It therefore became pretty evident that electricity was not developed until the steam issued into the atmosphere, and that the upper stop-cock derived its electricity from its contiguity to the jet. One circumstance alone seemed in some degree to militate against this supposition; namely, that the electricity of the cock E was greatly increased when the cock C was partially closed, as if the expansion which in that case took place in the upper tube rendered the steam electrical previously to its reaching the cock from which the jet was discharged. No negative electricity, however, could be discerned in any part of the apparatus; and without a development of negative electricity, I cannot see how positive electricity can possibly arise from expansion. The more probable explanation of the effect appeared to be, that the partial closing of the middle cock shortened the transparent or non-conducting part of the jet, and thereby caused the electricity to be more readily communicated from the opaque part of the jet.

"In consequence, no doubt, of increased accumulation of electricity which was thus occasioned in the highest cock, together with the unavoidable dampness of the surrounding medium, the upper glass tube, and the cock above it, became illuminated in the most singular and beautiful manner. Flashes of wavering light flickered round the exterior surface of the glass, and darted from it to the distance of three or four inches, while strong rays of electrical light streamed from the angular parts of the cock, and the flashes from the glass were accompanied by a snapping noise which was distinctly audible amidst the hissing of the steam, when the ear was advanced within a short distance from the tube.

"The upper glass tube was then removed, and as an additional test of the non-existence of free electricity in the interior of the boiler, a pointed wire was thrust down through the cock C and tube A into the steam, and effectual means were used to prevent the escape which would otherwise take place at the cock C, in consequence of the tap remaining open to admit the wire. Now this wire being insulated by the glass tube and communicating with the insulated cock C, must have rendered that cock electrical, if the steam were electrical in the boiler; but not the slightest indication of electricity could, under these circumstances, be found in the cock.

"Having withdrawn the pointed wire from the tube, another glass tube, of which the sectional area was about ten times greater than that of the one inserted in the boiler, was then attached to the cock C, in the same manner as the tube D had been before. The comparatively large bore of this tube allowed the steam to expand in a very great degree before it issued into the air, and caused it to be discharged in the state of low-pressure steam; but no diminution of electricity could be perceived in the jet, when thus attenuated; so that the electrical development does not appear to depend upon the degree of violence with which the steam comes in contact with the atmosphere."

At the same time that Mr Armstrong was making the foregoing experiments, Mr Pattinson was actively engaged in a similar investigation with the locomotive boilers on the Newcastle and Carlisle Railway. He performed similar experiments, with like results, respecting the intensity of the electricity of the steam blowing off from the safety valve; and found the intensity of the electricity to vary with the pressure of steam as follows:—At a pressure of 52 lbs., sparks were obtained three or four inches long. "At 40 lbs. per inch, the sparks became much less; the largest not reaching three inches. At 30 lbs., the largest spark did not reach two inches; at 20 lbs., it became barely an inch; at 10 lbs., not more than from one-fourth to one-half of an inch; and at 5 lbs. per inch pressure, the spark was hardly perceptible. But if, at any pressure, the valve was held down a few minutes, so as to suffer the steam to accumulate, and then suddenly opened, there was always a great increase, for an instant, of the electrical effects." With a very large conductor made of zinc tube, laced with copper wire, forming a hollow frustum of a cone, bristling with pointed wires, to collect the electricity from the steam, sparks larger in volume, but possessing no higher intensity, were obtained. The entire engine being insulated, by being placed on blocks of baked wood, the steam was blown off; when the boiler and engine became strongly negatively electrified, and the steam displayed a corresponding positive electricity. A point connected with the conductor held in the steam being brought near a point connected with the engine and boiler, the former beautifully exhibited the pencil denoting positive, and the latter the star denoting negative electricity.

When Mr Armstrong's attention was called to the phenomena exhibited by the boiler at Seghill, he formed the inference that the development of electricity was, in some way or other, dependent upon the nature of the water in the boiler; the more especially as the boilers on which he first operated were supplied with water taken from a coal mine, and which deposited a crust, as already mentioned, on the interior surface; and from failing to obtain electrical effects with a boiler supplied with rain water. A difficulty presented itself in explaining why, if the steam coming from the interior of the boiler was positive, the exterior of the boiler could be negative; in other words, why the opposite states of electricity exhibited in the steam coming from the interior and the exterior surfaces was not destroyed by conduction through the boiler plate. Dr Schafhaeutl suggested that the crust deposited by the water, or the interior surface becoming oxidated, formed a non-conducting medium, through which the electricity could not penetrate. These suppositions, however, were rendered unnecessary, when it was discovered that the steam was not electrified in the boiler; but acquired its electricity either on issuing into the air, or between that point and the boiler; and also, that the development of electricity was not dependent upon the quality of water in the boiler.

Our limits will not permit a more extended synopsis of the course of experiment pursued, to elicit satisfactory explanations of the phenomena; nor of the hypotheses advanced to make the development of electricity in steam account for electricity in the atmosphere, or the electric appearances observed in volcanic eruptions. We must come to the Lecture mentioned at the commencement of this article as having been delivered by Professor Faraday at the Royal Institution, containing, we think, the most decisive experiments, and satisfactory explanation, as far as regards the development of electricity during the efflux of steam.

The Professor commenced by exhibiting Volta's experiment, illustrating the production of electricity during evaporation. He put some water in a heated crucible, and showed the development of electricity during its evaporation. But there was one circumstance demanding particular attention in this experiment,—viz., that it was only under certain circumstances the presence of electricity was exhibited. If the water was boiled in the ordinary way, no indications of electricity were observed; or, if the water was thrown in while the crucible was too hot, no electric result followed. When the crucible was too hot, the water evaporated without ebullition, and without touching the sides of the vessel, being kept separate by a thin stratum of steam; but when it became cooler, the water comes in contact with the bottom and sides of the vessel, sudden ebullition and bursting of vapour take place, and electricity is liberated. "Upon this," says the Professor, "arises the notion—Is the atmosphere charged with electricity, by the evaporation of water ascending into the air and forming clouds? Is this glorious phenomenon which has been so frequently brought to our view lately, and which is so highly favourable for the exhibition of electricity—is this produced by evaporation from the surface of the earth or not?" In attempting to furnish answers to these queries, the professor operated, in the present instance, upon a boiler constructed on the locomotive plan, and insulated by standing on cakes of shell-lac. An insulated steam-pipe proceeded horizontally from the boiler,—interrupted, however, between the boiler and the jet by a metal globe for containing any liquid over the surface of which the steam was to be made to pass. An electrometer being attached to the boiler, and the steam blown off through the pipe, the leaves of the electrometer immediately diverged, exhibiting negative electricity. While the steam was escaping, sparks were drawn from the boiler; a jar was also charged, and a jet of gas lighted by the spark. By using an insulated conductor, formed of brass points and wire-gauze, through which the steam was made to rush, having an electrometer attached to it, the leaves instantly diverged, and on being tested, the electricity was found to be positive.

"Now came the inquiry into the cause of this development; and the great question is,—Is it due to evaporation? If so, it would be a ready transition to the explanation of atmospheric electricity and lightning. Although, as the results show, it does not arise from evaporation, and hence affords not the clue to elucidate the mystery which still hangs around those magnificent natural phenomena,—thus losing one portion of its interest, yet it possesses a peculiar beauty of its own, and one which will well repay the attention bestowed upon it. That it is not due to evaporation,—to the mere transition of water into vapour, was readily shown; for, on a portion of the steam-pipe being removed, although the steam was blown off with its pristine violence, not a trace of electricity was manifest. This illustrated two points,—viz., that it was neither caused by evaporation, nor by the mere issue of steam. On replacing the rest of the tube, and blowing off the steam, no electricity was obtained, until the globe above named was resupplied with water; nor then, indeed, did the effects return until such time as the passing steam had greatly raised the temperature of the water." The inference drawn by Mr Faraday from these facts is, that steam, as such, is only concerned in the production of these phenomena, inasmuch as it is a mechanical means of conveying the particles of water onward, and producing with them a powerful friction against the sides of the tube;—to the friction of which particles of water the whole effects are due.

Having gone thus far, a new series of curious circumstances occur. It is necessary for the production of electricity, that there be water in the globe, but unless the water be pure, electricity will not be evolved. This fact explains much of the conflicting results obtained by the original experimenters. Mr Faraday illustrates his position in the following words:—

"I have here some common Glauber salts; I will take a small portion of these crystals, dissolve them in water, and you will find that if I put the water into the globe, all these effects will cease. If I establish this point to your satisfaction, you will have no difficulty at once in ascertaining the kind of evaporation; because all ordinary water, at least all the water of the sea, must be more saline than this. I have used the salts that are in the sea, and they all have the same effect, that of entirely destroying the evolution of any electricity from the steam in the boiler. Now, here is a small portion of salts, and if we evaporate as long as we please, it will give us no electricity; but if you use common distilled water, free from impurities, you get the electricity directly; but put a little of this solution with it, and you perceive it is stopped immediately. I now put in a very small portion into this globe, and now I expect to have no electricity. First, the steam mingles the whole together. I have got no electricity in that water, all is perfectly quiet; but if I draw off this water and substitute distilled water, I shall have the electricity produced again. I will try this experiment; for it is a very singular one. I will draw off the impure water, and wash out the residue; and now you will see that the distilled water will bring everything up to its first state again. Now I have got cold distilled water: I will warm it up. I have hardly washed out the passages enough; but still there is the effect, the water comes forward. The water must be quite pure; even the common water which we use, which is nearly pure, will not answer the purpose. I will trespass a little upon your time, to show you that the water which is supplied by the Company at Paddington, and which for all ordinary purposes is very good, will not allow the formation of electricity. All I have to do is to draw off this water, and to introduce four ounces of this common water, and you will find it has salts enough in it to prevent any evolution of electricity as we had before with the pure water. I spent many weary hours in the closet in endeavouring to produce this evolution of electricity, and could not succeed: I could not tell why; until at last I used a portion of distilled water, and then I succeeded. Over and over again I have had these annoyances occur, until at last I arrived at the truth that a little admixture of saline matter gives a conducting power to the water, so as to prevent the formation of electricity. If I get a boiler which will stand a higher pressure than this, I find that water which is a little impure will give me electricity; proving that the greater pressure the more free the evolution, and that an interfering cause like this can be counteracted. I must not, however, stop longer upon these minutiæ, although they are very important, and help to set us clear from the notion that it is evaporation; for how can this electrical phenomenon, to which we have alluded, be caused by evaporation, when, as we have seen, in order to produce the effect we must have pure water, and when we know that there is no such water on the surface of the earth?"

The next point to which Mr Faraday directed attention was, the condition of the surfaces against which the water was rubbed to produce the electricity. By varying the distance of the conductor from the jet, anomalous results were obtained, which were explained by showing that when the friction was considerable, the gauze excited electricity; when the friction was less, the gauze only collected the electricity. Again, the electrical state of the boiler was changed, by introducing various substances into the pipe through which the jet of steam passed. On the steam blowing off, and the electroscope attached to the boiler indicating negative electricity, a little oil of turpentine was introduced into the tube amongst the steam, and presently positive electricity was indicated. By degrees as the steam carried off the oil of turpentine, the electroscope fell, until the boiler appeared in a neutral state, when it again assumed the negative condition.

This experiment is decisive as to the cause which produces the electricity. When pure water is carried along the tube, and rubbed forcibly against the jet, a high state of positive electricity is obtained; but on the introduction of a little oil of turpentine, each particle of the water becomes incased in a thin coating, which, lessening the friction, and forming indeed another rubbing surface, reverses the electrical result, until the oil being all forced out, the original positive state of the issuing steam takes place. That such is the explanation of the apparent anomaly, was shown by taking two balance scales, and placing one in contact with the surface of water, the adhesive attraction of which sustained considerable weight placed in the opposite scale. But the instant a single drop of oil of turpentine was applied to the surface of the water, the adhesion of the balance was overcome; showing an instantaneous diffusion of the oil over the whole surface. Many other substances introduced amongst the steam produce varying results in the electrical condition manifested. Even a stop-cock, in the interior of which was a little oil, unless well washed out with an alkali, was sufficient to vary the result. "Under these circumstances," says Mr. Faraday, "great as may be the production of electricity of this kind, to such a degree, that Mr Anderson will tell you he gets enormous sparks, twelve or fourteen inches long, by which he is enabled to fire

gunpowder and charge large batteries, all arising from the action of the steam; yet I am satisfied it has nothing to do with the phenomena of the thunderstorm and lightning flash. It is not by the process of evaporation that we get this electricity; but by the working of the water or other fluids, and their friction against other bodies. There is no substance in nature that stands so high in the scale of excitation as water. In former times we were used to consider cat's skin the most excitable substance; after that, the oxide of lime; but now they have both been found to be less excitable than water."

FLAX,

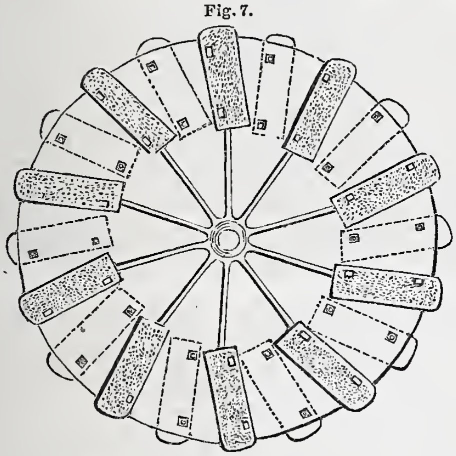
AND THE PROCESSES OF ITS MANUFACTURE.

CHAPTER II.

SCUTCHING—HECKLING—SPREADING AND DRAWING—SPINNING, WEAVING, AND BLEACHING.

We described in last chapter the processes of steeping and breaking. After passing through the breaking machine, the flax is scutched, which consists, as we have seen, under the

Fig. 7.



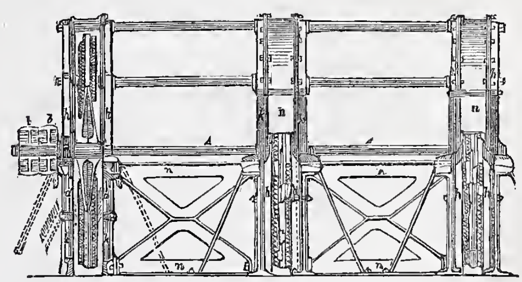
ordinary process, of being subjected to the action of rapidly-revolving wooden blades, fixed on radial arms on a central shaft. Mr. Plummer, however, has substituted for the radial arms a revolving metal disc, on which brushes are fixed, instead of the rigid blades of the ordinary scutching machine. The engraving (fig. 7) exhibits this disc, with the brushes fitted to it, which revolves horizontally, and is shown in the figure as seen from above. The dotted lines show the position of the brushes on the other side of the disc.

The rigidity of the blades in the ordinary machine, the rapid rate at which they revolve, and the liability of the flax to be blown about by the currents of air created in the box or case in which the blades revolve, causing it to be wound or curled on the radial arms, and thereby its ends to be cut off and reduced to the state of tow, form the principal objections which Mr. Plummer endeavoured to obviate by his improved scutching machine. The prevailing principle of his improvements is, to effect the cleaning of the flax without subjecting it to any unnecessary violence. The processes of breaking, scutching, cutting, and heckling, are those operations on which not only depends the future quality of the yarn, but even the amount that can be spun (of good texture) out of a certain given quantity of flax. The tendency of the rigid blades of the old scutching mills, and of any unnecessary violence of action in the other preparatory processes, is to reduce a very large proportion of the flax to the less valuable state of "tow." By the ordinary methods, more than one-half of the original material operated upon, is actually reduced to this state, in which its value is fully 50 per cent. below the same material in that more useful state, in which it is designated as "line." We have stated, that the fibres which constitute the valuable portion of the flax plant are naturally cemented together by a strong resinous gum, which it is the object of the chief preliminary operations to get rid of, along with the other attendant dirt and impurities. Acting on the idea that the machines generally in use for effecting this purpose, impair rather than sustain the peculiar character of the fibre, Mr. Plummer considered that, in the scutching and heckling, great improvement "might and ought to be made; one which, in its ultimate results, might materially affect the subsequent stages of preparing and spinning linen yarns: that, in truth, it was not so much the form and kind of the machines, as the mode of treating the fibre when submitted to those machines, which stood in greatest need of improvement; and that, if the idea of treating a long and generous fibre with tenderness instead of harshness could be carried out, not only would a considerable saving in every respect be obtained, but also greater facility be given for avoiding cutting, and for dealing with flax in the original length and integrity of its fibre."

In accordance with these ideas, Mr. Plummer acted on the principle of substituting elastic materials, as brushes, for the rigid instruments generally applied to the flax; and he states, as the assumed advantages of this improvement, that, by means of his new machines, greater cleanness is produced, both in the "line" and "tow;" that, from parallelizing the fibres by the brushes, before passing them through the heckle pins, the yield of "line" is considerably larger from the same amount of material than by the common process; and farther, that by this improved system a material saving is effected both in the heckles of the machines and in the filleting of the cards, while the ultimate produce of the operations is a cleaner, leveller, and brighter yarn, attended with less waste. The elastic materials were first applied by the inventor in the heckling machines, and it was by observing their beneficial effects in this operation, that he was impressed with the idea of substituting brushes for rigid blades in the scutching mill. His expectations appeared to be fully realized by several successful experiments on a large scale, which showed that the brush, properly applied, was a highly effective instrument for scutching flax.

The engraving, fig. 8, exhibits a front elevation of the rotary disc scutching mill. A, is an axle, having its bearings in an independent framing, *k k*, of metal, with a lining of deals, *l l*, the upper portion being made to open. The metal piece, *m m*, at the front end, being secured by three bolts, can be readily removed for the purpose of changing the brushes in the disc. The framing is stiffened by cross pieces, *n n*; *b b*, are pulleys, by which a rotatory motion is imparted to the axles. The top, *i*, of the scutching-board, *h*, is placed a little

Fig. 8.



above the centre of the axle, A. The heckle-comb, O, is composed of steel wire.

The brushes may be fixed either to one side, or both, of the disc. In diagram, fig. 7, they are exhibited as fixed on both sides, fitting into alternate recesses. It is one advantage possessed by the disc form of the machine, that a greater number of brushes can be attached to it than to the radial arms of the ordinary machine: they may be attached at any desired angle. The back end of the casing, within which the disc revolves, is left open to allow of a free passage of air, carrying off the dirt and refuse evolved by the process, and the casing

is contracted at the top to prevent the air from being carried round in the same direction as the disc. The fibres of flax and other adhering substances are stripped from the brushes by heckle-combs attached to metal doors, or traps, which are kept closed by lever-handles. When the traps are opened, the heckles fall back, and can thus be easily cleaned. The brushes are removed at pleasure from the disc, by simply pressing the spring catches by which they are held in their position."

CUTTING.

Having passed through the scutching mill, the flax is made up into bundles, which are called "stricks," and in this form is delivered to the factory to pass through the subsequent operations of cutting, heckling, and drawing, before being spun into yarn. The lengths of the fibres in the stricks vary from twenty to thirty inches, and the middle portion of each length is considered the most valuable, being on that account reserved for spinning the finest yarn. It is necessary, therefore, to divide the lengths into three parts, and this is the next process in the manufacture. It is effected by a breaker, or cutting roller, on each side of the central shaft of which are two sets of wheels grooved in their circumferences, and working into each other. The pressure between them is maintained by a proper adjustment of a series of weighted levers, the shaft of the upper pair moving in a slot in the framing. Those on each side of the breaker revolve in different directions. The flax is laid across the grooved wheels, and these, slowly revolving in opposite directions, bring it into contact with the breaker, which, being composed of wrought-iron rings having elliptical projections on their external surfaces, and performing three hundred revolutions per minute, breaks the flax fibres into portions of any required length, without absolutely cutting them, which would unfit them for spinning. When one end is thus cut off, the flax is reversed, and again passed through the machine, and thus it is divided into three parts, which are laid in separate heaps.

HECKLING.

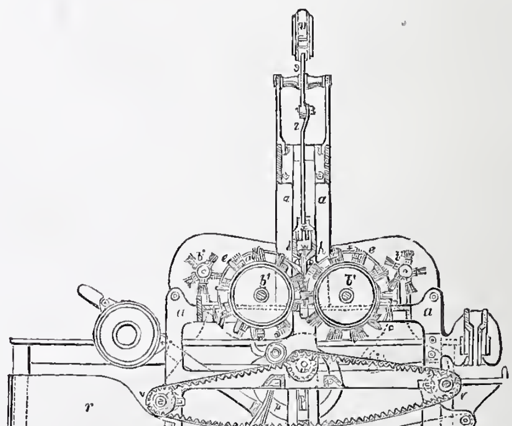
The flax is now ready for the process of "heckling,"—a process so highly important in the manufacture of flax, that the value of the fabric prepared from this article depends in considerable measure on the efficacy of the operation. The principal object of heckling is to separate the fibres from one another, to parallelize them for spinning, and to disengage the "tow," which, as already stated, is the least valuable portion. This important operation has always, till a recent period, been performed by hand; and even still it is a subject of some debate and doubt, whether it is possible, by any complication of machinery, however ingenious, to perform it with that nicety of touch which is characteristic of the operation in the hands of a skilful workman. The rationale of the process, whether performed by the hand or the machine, is equally simple. It consists in drawing the flax through between a series of pointed wires, which are fixed with the points projecting upwards, at a greater or less distance from each other, according to the stage of advancement in the operation. The flax is thrown lightly on the points, and drawn through in such a manner as to separate and disentangle the fibres. In short, the heckling is simply a combing process. When performed by hand, the operative stands at a bench, in the front of which are fixed a number of the pointed wires, called "heckle-teeth," four or five inches in length, but varying in thickness and contiguity of position, according to the stage of the process. Thick wires are used at the commencement, and these, as the operation proceeds, give place to more slender wires, till the requisite degree of fineness is attained. The end of the strick of flax, as it is technically called, is wrapped by the operative round his right hand, and the loose end is thrown over the wires, while the left hand is placed at the back of the row of teeth in such a manner, that the upper or forefinger regulates the depth to which the fibres are permitted to penetrate the teeth. A deeper or lighter hold of the teeth is thus taken, according to the state of the flax and the choice of the operator.

It will be observed, that considerable difficulty must have been felt in adapting machinery to this variable process, which does not consist in one uniform operation, like the tearing asunder of cotton, but requires a peculiar adaptation to the varying circumstances of the fibre—sometimes a lighter, and sometimes a deeper touch—some arrangement, in short, which might supersede, not only the manual, but also the mental labour involved in the hand-heckler's experienced manipulation. This apparently insuperable difficulty has, however, been overcome, by a somewhat complex, but very ingenious arrangement, which leaves little to desiderate in point of farther improvement.

The simplest idea of the heckling machine is a cylinder, studded on its outer surface with heckle-teeth, to which, as the cylinder revolves, the flax is applied by fixed holders, instead of the hand of the operative. The flax is suspended from the holders, which are gradually pushed forward, so as to bring the flax successively in contact with the different rows of heckles, proceeding from the coarser to the finer. It is farther desirable that the ends of the streaks be subjected to less dressing than the middle parts, and for this purpose the table sustaining the holders is made to rise and fall, so as to be highest or farthest from the heckles when the flax is first inserted, and gradually descending to give it a deeper hold as the heckle-teeth pass up through the flax. When one row of teeth has performed this operation, the holder is pushed forward to the next; and when the table has again reached its highest point, the same operation is repeated with a finer series of heckles, beginning, as before, at the outer ends of the flax.

The rising and falling of the table is made available in Mr. Plummer's machine for pushing along the holders, so as to place them successively above the different sets of heckles. The manner in which this motion is produced, and the other details of the machine, will be understood by referring to the diagrams, figs. 9 and 10, representing a side and end elevation of Plummer's double-cylinder heckling machine, adapted to

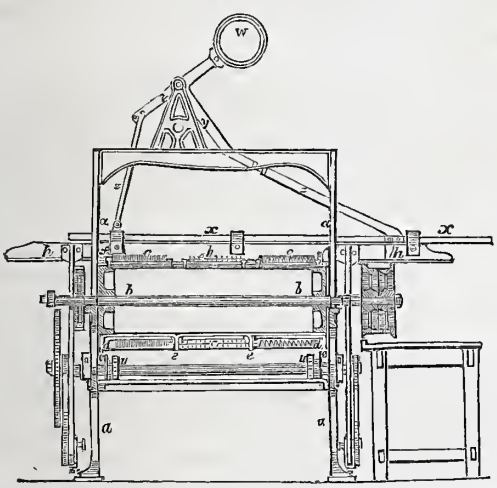
Fig. 9.



the dressing cut or short flax, and in which elastic brushes are combined with rigid heckles. The two revolving cylinders, b' b', are mounted in a framework, a a; and the rigid heckles, c', attached to their peripheries, are intermixed with the sets of elastic brushes, c c, in any way that may be deemed most advisable. The cylinders revolve inwardly, or in opposite directions, and the rows of heckles and brushes on the one cylinder are placed in an alternating order, in regard to those of the other cylinder. Connected with these are loose stripping bars with guards, which, besides regulating the depth to which the heckles or brushes shall penetrate, throw down the tow from the brushes and heckles. There are likewise two smaller cylinders, b^2 b^2, fitted with brushes for cleaning the working brushes and heckles, c c'. The mechanism for lifting the table, or trough, consists in a combination of pinions,

wheels, cams, straps, pulleys, and levers. There is nothing peculiar in this part of Mr. Plummer's machine. The motion is produced by a cam, working on a friction-roller, placed near the extremity of a lever, which is sustained and made to rise (when depressed) by straps connected with another lever, to the outer end of which a weight is attached. This second lever is alternately depressed by the cam and raised by the other lever, thus producing a reciprocal movement of a vertical rod, with which the table is connected. When the trough or table is raised, it pushes up a rod, *z*, fig. 10, which is connected to the long arm of the bell-crank, *y*, mounted on a standard attached to the top of the framework, as shown in the drawing. When this arm is raised by the rod, *z*, the weight, *w*, falls

Fig. 10.



over, and causes the other arm of the bell-crank (on the right hand of the figure) to pull in the rod, *z′*, which draws forward, or moves from right to left in the figure, the finger bar, *x*, to an extent sufficient to advance the holders the breadth of one set of heckles, or brushes.

The finger bar, *x*, is a rod, from which depend moveable fingers, so constructed as to catch the end of the holders, and push them along the trough, or table, in one direction. The finger is jointed, so that, when passing, say from right to left, it has no effect on the holders; but when the bar reverses its motion, the finger, being prevented by a catch from inclining backward, shoves the holder along at the proper time, and thus places the flax over a new set of heckles.

In Mr. Plummer's machine, the tow and shive, or dirt, doffed or thrown down from the heckles and brushes, is received upon an endless chain of bars, instead of the inclined grating in other machines. The bars extend the whole length of the machine under the heckles and brushes, and are connected together by two side bands. They revolve round two friction pulleys, *v v*, fig. 9, and take into two pinions, *u u*, one on each side. By these pinions, rotation is given to the chain from the first mover. The openings between the bars permit the shive, or dirt, to fall through between them on the floor, while the tow is carried forward on the top of the bars, and delivered into the trough, T′. To separate the tow doffed from each set of heckles or brushes, the space between the endless chain of bars and the cylinders is divided by partitions into as many compartments as there are sets of heckles or brushes; and the receiving trough, T′, is also divided into a corresponding number of compartments.

The double cylinder machine accomplishes the important object of dressing both sides of the streak of flax at once, whereas, in the common single cylinder machine, the holders must be passed through the machine a second time, but in a reverse position; that is to say, the side of the holder, which in the first operation was to the front, is then turned to the back, and the operation repeated. Different mechanical contrivances have been adopted to save the trouble attendant on this shifting of the holders by hand. By one arrangement, two heckling machines are employed, placed near each other, end to end, but revolving in different directions: and the flax, when dressed on one side by the first machine, is passed through with its holder to the second, the cylinder of which, revolving in a contrary direction, takes up the ends of the flax and dresses it on the other side. Again, by Carmichael's method, the holder is first placed on the outer end of the table or trough, and pushed along till it reaches a small fixed table, which, by its descent, allows it to be heckled on one side; thereafter it is passed along till it reaches another table, which is caused by the machinery to revolve, and by this means the sides of the streak not previously operated upon are turned round, and dressed likewise. The semi-revolution of the table at stated intervals is easily produced by a bell-crank, connected with a ratchet-wheel, which communicates by toothed wheels with the table. The rising and falling of the bell-crank, which works into the notches of the ratchet-wheel, is produced by a cam, and the movement of the wheel from notch to notch, causes the table to move half round at certain intervals, corresponding to the rising and falling of the table or trough.

These contrivances are rendered unnecessary by the simultaneous action on both sides of the flax of the double cylinder machine; and as it is further desirable to have the streak most dressed at the middle, or thickest part, the ends being less operated upon, Mr. Plummer effects this by the following ingenious arrangement. One of the cylinders, *b′*, fig. 9, is made to oscillate by means of the link, *h′*, which, as it rises and falls with the lifter to which it is attached, moves the cylinder in a horizontal direction from the other cylinder, so that the two cylinders are placed wider apart when operating upon the ends of the flax. The ends are thus prevented from being overdressed, and the full power of the heckles or brushes is applied on the body of the streak.

We have previously stated, that in Mr. Plummer's machine there are loose stripping bars with guards, that not only regulate the depth to which the heckles or brushes shall penetrate, but likewise doff and throw down the tow from the brushes and heckles. In the ordinary heckling machine, the tow is stripped from the heckling wires of the cylinder by means of a small cylinder revolving in an opposite direction, the periphery of which is covered with wire-carding leathers; and the tow adhering to this small cylinder is stripped off by a comb or knife, which stretches along the whole length of the cylinder, and is moved rapidly up and down by a lever impelled by a small crank or eccentric.

To complete our account of the heckling process, it now only remains to describe Mr. Plummer's improved holders, which perform so important a part in the operation. A view of one of these is given in fig. 11, a cross section, and fig. 12, a longi-

Fig. 11.

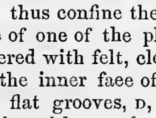
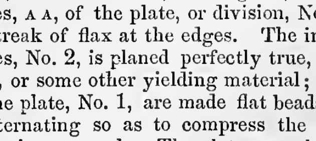


Fig. 12.



tudinal section. The instrument consists of two metal plates, Nos. 1 and 2, connected by the screw bolt, s, with flanges, A A, at their upper edges, by which they are supported in the holder-trough, *h* (fig. 10). The plate, or division, No. 2, has two flanges, B B, one at each end, as in fig. 12, which come within the flanges, A A, of the plate, or division, No. 1, and thus confine the streak of flax at the edges. The inner face of one of the plates, No. 2, is planed perfectly true, and covered with felt, cloth, or some other yielding material; but on the inner face of the plate, No. 1, are made flat beads, c, and flat grooves, D, alternating so as to compress the flax firmly, without crimping it too much. The plates are chamfered off at their under edges, E, to admit of the holder coming lower down. The advantages of this mode of construction are, that the pins, or studs, ordinarily used to confine the outer edges of the streaks, are dispensed with; a greater breadth is

obtained on which to spread the streaks; and the holder is narrowed and rendered easier to work.

Having thus completed our account of the important operation of heckling, and the latest improvements in the mechanism for that purpose, we now proceed to describe the ulterior processes to which the flax is subjected.

SPREADING AND DRAWING.

The next operation is that by which the heckled flax is brought to the condition of a long narrow band, or riband, termed a "sliver." The machine by which this is effected is called the "spreading machine." Two tables, made of unequal length, for the purpose of allowing two individuals to supply the machine with flax simultaneously, without interfering with each other, are placed at the back of the machine. The surface of the tables is an endless sheet, or band, passing over rollers placed at each end, which slowly revolve, communicating to the table, or band, a motion uniformly progressive. The streaks of flax which have been heckled, are spread one by one on the table, so that the end, or thinnest portion of each streak, lies at the thickest part of the one immediately preceding it, which it overlaps, and thus an uniform thickness is preserved throughout the whole layer of flax spread on the table. Two detaining rollers, revolving in contrary directions, receive between them the flax, which is guided along by a polished iron plate, and pass it on to a sheet of heckle points, which project upwards, and advance with a progressive movement from the back to the front of the machine. It is requisite that, in the sliver, the fibres should lie parallel to one another, and the purpose of these heckle-teeth is further to comb, separate, and parallelize the fibres. The flax, having passed the heckle-teeth, proceeds onward between drawing or pressing rollers. The surface of the upper of these rollers is covered with leather; they revolve with a greater velocity than the detaining rollers; the consequence of which is, that the fibres of flax are rendered thinner, more parallel, and more uniformily diffused, in passing through between them. From the drawing rollers, the flax is delivered to the sliver plate, in which are four bevel slits, which receive the slivers from as many pairs of rollers. The slits afterwards unite into one, and they are finally compressed between calender rollers, from which they are delivered to a tin can, placed beneath them.

The registration of the length of the sliver is effected in this manner. At the extremity of the axis of the lower drawing roller, a small endless screw is placed, which works into a worm-wheel, and on the axis of this wheel is placed another endless screw, driving a second wheel. In the rim of the latter, a pin or stud is inserted, which, at each revolution of the wheel, communicates with a small bell by means of a spring.

We have seen that, between the detaining and drawing rollers, the flax is penetrated by heckle-teeth, which have likewise a slow progressive motion. There are two kinds of mechanism for producing this motion, respectively known as the "sheet gill," and the "screw gill." The former, which is the older method, consists of an endless chain moving round two pulleys, by which motion is communicated to the heckle-band. The latter moves in a guide, which is not circular, but horizontal at top, and thus the teeth, when in contact with the flax, move in a horizontal direction, except at the points where they enter and pass away from the flax. By the "screw gill," which is now most generally used, the heckle-teeth are always presented upwards to the flax, which is considered an advantage. In this machine the heckle-teeth are placed in bars, supported at their extremities by guide rails, fastened to the insides of the sockets, in which revolve endless screws. Two of these screws are placed at each side of the machine, one above the other, and working in contrary directions. The upper pair of screws carry forward the heckle-bars or "fallers," to the drawing rollers; the bars are then received on the lower pair of screws, and by them are carried back, when not in contact with the flax, to the detaining rollers. The teeth, always projecting upwards, are thus presented perpendicularly to the flax at every stage of the movement.

Having passed through the "spreading machine," the slivers are then carried through the "drawing frame," which is not materially different from the former. The object of this additional operation is simply to impart to the sliver increased fineness and uniformity. The arrangement of the rollers and heckle-teeth is much the same in this machine as in the other; but, instead of the spreading tables, a curved polished plate is placed at the back, immediately under the rollers; and from this plate the slivers are passed through, as before, between a similar series of rollers, &c. They are generally passed twice through this machine, to give to the fibres as much uniformity and parallelization as possible.

Before being spun, or twisted into yarn, the slivers are still farther attenuated in the "roving frame," from which they emerge for the first time in the shape of a soft twisted cord, and this is wound upon bobbins, preparatory to the operation of spinning.

SPINNING, WEAVING, BLEACHING.

The flax is now ready to be made into yarn; and the future operations, as spinning, weaving, &c., lose their distinctive character in being analogous to that of the cotton manufacture, to which we shall devote a separate article. We may state, however, that the fibres of flax have not the same tendency to entangle themselves together as those of cotton; and although, for coarse purposes, flax can be spun dry, and is so, to a great extent, in the Scotch factories, yet, for the finer yarns, it is necessary to moisten the fibres with water to make them adhere to each other, and also to make them more pliable and easy to twist. Till lately, cold water was used for this purpose, but it has been found a great improvement to substitute water at the temperature of 120°. This has the effect of allowing a much finer and more uniform thread to be spun, and double the length to be obtained from a given weight of flax. The trough containing the warm water extends the whole length of the spinning frame, and the moisture thus communicated to the fibre causes a dewy spray to be continually thrown off by the rapid motion of the spindle. On this account, the spinners are accustomed to wear water-proof aprons, otherwise their clothes would soon be completely wetted by the warm spray.

By doubling, the yarn is made into linen thread, which is bleached, and then formed into balls or reels. The yarn itself, when wound upon reels, is made up into leas, hanks, bundles, &c. In the two-and-a-half yard reel, 120 threads of $2\frac{1}{2}$ yards, or 300 yards, are equal one lea; 10 leas are equivalent to one hank, or 3,000 yards; and 20 hanks constitute one bundle, or 60,000 yards. In the one-and-a-half yard reel, 100 threads of $1\frac{1}{2}$ yard, or 150 yards, equal half a lea; 10 half leas equal 1,500 yards, or one hank; and 40 hanks equal one bundle, or 60,000 yards. In the former, three bundles, and in the latter, six, are usually put together in one bunch. The fineness of the yarn is reckoned by the number of leas to the pound weight. The common limit of fineness for ordinary linens is about 150 leas to the pound; and yarns from this limit, up to 240 leas, are spun by machinery for the manufacture of Irish lawns and coarse cambrics; but for fine cambric or lace, the number of leas to the pound is from three to four hundred. In *sorting* the heckled flax, or *line*—an operation performed before the spreading and drawing—the line-sorter, judging of the various degrees of fineness by the touch, separates the stricks into several divisions, according to quality. He is seated before a sorting-box, which is a kind of table, containing several divisions for receiving the various qualities of line, and these are distinguished as 2 lbs., 3 lbs., $3\frac{1}{2}$ lbs., 4 lbs., 5 lbs., &c., according to the weight per bundle to which the particular quality would spin when these denominations were given; and although, from improvements in machinery and other causes, $5\frac{3}{4}$ line can now be spun to the size of 3 lbs. the bundle, and even finer, the same designations for the same qualities of line are still retained. Flax is tied up in bundles of 16 lbs. or 24 lbs., the former termed the English, the latter the Scotch stone.

The arrangements of the large spinning-mills are very complete, and well repay a visit. In the capacious stores may be

seen samples of flax of various qualities, the produce of various countries, and varying in price from £25 per ton for Egyptian, to £140 per ton for Belgian and French. Where fine yarns are spun, the quantity of flax worked up is about 25 tons per 1000 spindles per annum; for coarse linen yarns, the quantity varies from 30 to 50 tons per 1000 spindles. The power required to drive the machinery is estimated at about 6 horse power for every 500 spindles. This is a much higher power than that required in cotton-mills, where 500 spindles may be driven by 1 horse power. The greater number of mills spin the medium qualities only—in some the finer numbers, 200's to 250's are produced. For these the choicest samples of flax are chosen, the manipulation is more careful, and the machinery more delicate, than with the coarser yarns. In these, too, the increased value which labour gives is more prominently shown, by the difference between the price of the raw material and the manufactured article. For instance, a bundle of 240 lea yarns weighs 9 lbs. 14 oz., its selling price is £8; while the maximum value of the material itself, the flax, could not exceed 20s., showing the relation between the values of the raw and of the manufactured article to be as 1 to 8. In the coarse yarns this great increase is no longer perceptible. A bundle of 40 lea yarns weighs 30 lbs., and sells for 24s. 9d., the value of the raw material being about 15s., or, in relation to the manufactured, as 1 to 1·6.

HORTICULTURE.

CHAPTER III.

THE SPECIES AND VARIETIES OF OUR CULTIVATED FRUITS.

There is not, perhaps, a more difficult task in rural economy than the stocking of the orchard. The varieties of the common fruits have become so numerous, that it is almost impossible to tell upon which to decide. One has, in fact, to select a few dozen trees out of thousands; and, what is worse, the number is so great, that we are obliged to trust, in some degree, not upon personal observation, but upon statements in gardening books and seedsmen's lists, neither of which are, in all cases, to be depended upon, and which, as we know to our cost, are continually contradicting one another. The following is an account, as far as we can make out, of a proper selection for a small orchard in Scotland.

In making the selection, we have been guided partly by the hardihood, and partly by the productiveness of the trees, partly by the quality of the fruit, and partly by the time the fruit ripens and remains good, our object being to obtain a supply over as long a period as possible.

APPLES.

The apple tree is *the* fruit tree of Britain, as the vine is that of more southern countries. With very little trouble it comes to perfection, even so far north as the Shetland islands. By management, a supply may be had from July to April. Its fermented juice, or cider, is a very wholesome beverage, little used, however, in the northern part of the country (save in the form of adulterated wine); and, by distillation, brandy can, as is the case extensively in the north of France, be obtained from it.

The apple tree has been in cultivation for a very long period. The Romans grew it, and Pliny was acquainted with twenty-two varieties. Parkinson, in his work referred to in a previous article, enumerates fifty-seven. Hartlib states his belief that, in his time, there were five hundred; and at the present day, if we may believe the lists, there are probably more.

The following is our selection; *d.* stands for dessert, and *k.* for kitchen apples:—

Ribston Pippin, *d.*,	ready for use	Jan., Feb., March, Oct., Nov., Dec.
Hubbard's Pearmain, *d.*,	"	January, February, March.
Scottish Gogar, *k.*,	"	January, February, March.
Cockpit, *k.*, . .	"	January, February, March.
Wellington, *k.*, .	"	April.
Green Fulwood, *k.*,	ready for use	April.
Hoary Morning, *k.*, .	"	April.
Juneating, *d.*, . .	"	End of July.
Codling, *k.*, . .	"	July, August.
Hawthornden, *d.*, .	"	August, September.
Crofton, *k.*, . .	"	August, September.
Early Harvest, *d.*, .	"	August, September.
Autumn Pearmain, *d.*,	"	September.
Spring-grove, *k.*, .	"	September.
Kentish, *k.*, . .	"	September.
Keswick, *k.*, . .	"	September.
Dutch Codling, *k.*, .	"	September and following month.
Blenheim Pippin, *k.*,	"	September.
Grey Rennet, *d.*, .	"	Sept., Oct., Nov., Dec., Jan., Feb.
Franklin, *d.*, . .	"	October and subsequent months.
Golden Pippin, *d.*, .	"	Nov. and subsequent months.
King of the Pippins, *d.*,	"	Nov. and subsequent months.
Golden Rennet, *d.*, .	"	Dec. and subsequent month.
Cockle Pippin, *k.*, .	"	Dec. and subsequent month.*

None of the above are suitable for making cider. An apple that will make this beverage well, must be rough and austere, and the best cider apples are not eatable at all. A kind called Woodcock, and an artificially produced cross between a Siberian crab and a pearmain, are much commended.

PEARS.

The pear tree has been cultivated from time immemorial. The pear is principally used as a dessert fruit. From its expressed juice (but on a small scale) perry is made; it is also used for stewing, and on the continent it is pared and dried in an oven, in which state it will keep good and fit for use for an indefinite time. The following twelve varieties seem the best suited for a small orchard:—

Colmar, *d.*, .	in season in	January, February.
Muirfowl Egg, *d.*, .	"	January, February.
Catillac, *k.*, . .	"	January, February.
Pawmeg, *k.*, . .	"	January, February.
Duchess d'Angouleme, *d.*,	"	February, March.
Beume Rance, *k.*, .	"	March, April.
Madelane, *d.*, . .	"	July.
Jargonelle, *d.*, . .	"	August, September.
Summer Rose, *d.*, .	"	August, September.
Summer Francreal, *d.*,	"	September.
Bergamot, *d.*, . .	"	October.
Napoleon, *d.* and *k.*, .	"	Early winter.

The best perry pears are very austere ones. One called Roughcap is commended for this purpose.

QUINCE.

This tree is little grown, but a quince or two is sometimes required to impart a flavour to apples in tarts. One tree is sufficient for a small orchard, and the kind called the pear quince is perhaps the best to select.

MEDLAR.

This tree is seldom grown. The Nottingham medlar is said to be the best sort. The fruit is not eaten until it is in a state of incipient decay.

PLUMS.

The plum is indigenous in Britain. It is used as a dessert fruit, and also for preserves. The following list will give a prolonged supply for dessert:—

Washington, . .	ripe in	August.
Early Violet, . .	"	August.
Drop d'Or, . .	"	September.
Green Gage, . .	"	September.
Coe's Golden Drop, .	"	September.
Cowper's Large Red, .	"	September.
Damson, . . .	"	September and October.
Magnum Bonum, .	"	September and October.

CHERRIES.

Cherries have been a favourite summer fruit in this country for a very long time. They are also used for pies, preserves,

* In this and the subsequent lists, it is not meant that the varieties will not sometimes keep longer than the months stated, but the months put down are when they are most in season.

&c., and are kept also in brandy or silent spirit. The following is our selection:—

Early Purple Griotte,	ripe in	June.
May Duke, . . .	"	June.
Royal Duke, .	"	July.
Waterloo, . . .	"	July.
Kentish, . .	"	July and August.
Black Tartarian, . .	"	July and August.
Amber, . . .	"	September.
Morello, ...	"	September, and often later.

APRICOTS.

Apricots were introduced into England by Henry VIII.'s gardener. The four following sorts are suitable for a small orchard:—

Moorpark, . .	ripe	end of August, and best kind.
Hemskirke, . .	"	beginning of August.
Royal, . . .	"	beginning of August.
Turkey, . .	"	September.

PEACHES AND NECTARINES.

These are the same fruit, but the peach has a downy, the nectarine a smooth skin. They will scarcely ripen in the open air in the northern part of the island. Perhaps the red nutmeg peach and Fairchild's early nectarine are the best two sorts to fix upon.

MULBERRIES.

The mulberry tree only occasionally ripens its fruit in the northern part of the island. There is only one kind of it, and when it does ripen its fruit, this happens in August and September.

NUTS.

The three best sorts are—hazel, red-skinned filbert, and cob nut.

WALNUTS.

The walnut only occasionally brings its fruit to maturity in the northern part of the island. The best sort is said to be the Highflyer of Thetford.

GOOSEBERRIES.

This much-admired fruit is used in an unripe state in pies, as a dessert fruit, and preserved when ripe; and a most excellent wine is obtained by fermenting its juice with sugar. No less than three hundred varieties are put down in the lists, and great confusion exists regarding them. The following is Neill's abridgment of the sorts recommended by the London Horticultural Association:—

a Red:—Red Champagne, Ironmonger, Rob Roy, Small Red Globe, Keen's Seedling, Lord of the Manor, Leigh's Rifleman, Red Warrington, Wellington's Glory.

b Yellow:—Yellow Ashton, Yellow Champagne, Golden Yellow, Smiling Beauty, Smooth Yellow, Yellowsmith, Rumbullion.

c White:—Bright Venus, White Champagne, Cheshire Lass, White Crystal, White Damson, White Honey, Whitesmith.

d Green:—Green Gascoigne, Pitmaston Greengage, Langley Green, Green Laurel, Gregory's Perfection, Green Walnut, Jolly Tar.

CURRANTS.

Currants are divided into black, white, and red. There are two varieties of the black, the common and the Naples; the two most important of the red are the common and the red Dutch, and of the white, the common and the white Dutch.

RASPBERRIES.

The two best kinds are red and yellow Antwerp.

STRAWBERRIES.

As with the gooseberries, the varieties of the strawberry are in a state of extreme confusion, which has been rendered greater by the writers putting down several species of strawberries. The following will perhaps afford a supply from June to October.

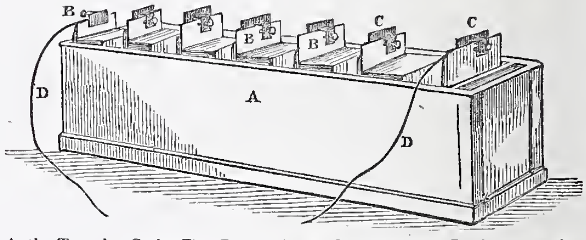
Old Scarlet.	Old Pine.
Keen's Seedling.	Hautbois.
Elton.	Alpine.

THE ELECTROTYPE.

CHAPTER VI.

OBSTRUCTIONS TO THE GALVANIC CURRENT, AND MEANS OF OVERCOMING THEM.—FURTHER DIRECTIONS FOR MAKING MOULDS.

It has been stated, that when two metals are immersed in an exciting fluid, they may be so connected as to form a battery, whether by a metal or by a solution; but that all the metals are not equally effective as connections. Pieces of copper and zinc being connected by a fine copper wire, the chemical action and the electrical current are in full activity; but if iron wire of the same diameter be substituted for the copper wire, it would become red hot, and probably would ultimately fuse, while the chemical action upon the zinc would not be so great. Hence we conclude that iron is a worse conductor of electricity than copper, the same amount of surface not being capable of allowing the same quantity of electricity to pass through it in the same time. Hardly any two metals are alike in this respect; solutions employed as media of connection are subject to the same variety in their conducting powers. For example, one plate of copper and zinc in acidulated water produces electricity of sufficient power to pass through a solution of sulphate of copper forming the connection between the two terminals; but if a solution of cyanide of copper be used instead of the sulphate, no electricity will pass, as the resistance of this solution is greater than the power generated by the one pair can overcome. Several causes obstruct the passage of the current; among others there are the distance through which it has to pass, the nature of the solution, and the temperature. Our object at present is to discuss the means of overcoming such obstructions: this is effected by what is termed a compound arrangement of batteries, which is made by connecting the zinc of the one pair to the copper of the next pair, and so on through whatever number of pairs is found necessary. The accompanying figure represents a compound arrangement of a common acid battery.



A, the Trough; C, the Zinc Plates; B, the Copper Plates; D, the connecting wires constituting the Poles, or terminals of the Battery.

The copper in this battery is shaped thus: a piece of wood is placed upon the bottom of the copper, and the zinc-plate z is made to rest upon it, or, what is better, the groove of the trough in which the zinc is placed, may stop a little above the copper, so that the one does not touch the other; the bent part of the copper at z' is connected with the zinc of the next pair; and the last zinc of the series at one end, and the last copper at the other, are isolated when the battery is not in action, and constitute the terminals or poles of the battery. As with a single pair, there is no galvanic action until these two poles are brought into connection. By such arrangements, the force or power of the electric current to overcome resistance is increased according to the number of pairs used. We have already said that the quantity of electricity obtained from a battery bears relation to the amount of surface of zinc in contact with the acid; thus, if 6 square inches of surface were immersed in the acid, it would yield only one-half of what 12 square inches would give. It must not be supposed, however, that as in the above battery there are six pairs of plates, the quantity of electricity evolved should be six times that given out by one pair. For example, if each zinc-plate have 6 inches of surface immersed in the acid, the total surface exposed to it will be 36 inches; nevertheless, the quantity of electricity evolved is only the same as before: this is always the case in a compound ar-

rangement. The quantity of electricity obtained is only in relation to the surface of one pair, as the others merely communicate energy to that quantity; and, further, supposing that in the above arrangement one zinc had only three square inches of surface immersed in the acid, although the remaining 5 may have each of them 6 square inches immersed, the quantity of electricity is only that due to 3 square inches. It must be remembered, then, that the least surface of zinc exposed in the arrangement, always determines the amount of electricity produced. For electrotyping on a small scale, compound batteries are unnecessary; but for large surfaces and deep-cut figures, or in practical applications to the arts, intensity or power is of great consequence. A considerable difference in the power of the current can be obtained sometimes from a single pair, by merely using a different exciting fluid in the battery. The relative differences will be apparent from the following list, in which a Daniells' battery is taken as unity. A copper and zinc being separated by a porous diaphragm, the copper is placed in a solution of sulphate of copper, and the zinc in dilute sulphuric acid.

Let the power generated by this battery, be expressed by 100. A solution of common salt, instead of dilute acid, gives 106; a solution of sal-ammoniac gives 116; and a solution of caustic potash gives 138.

If platinized silver be used instead of copper, having dilute sulphuric acid in both divisions, there is obtained a power equal to 65. A solution of common salt with zinc gives 68. A solution of caustic potash with zinc gives 98. If platinum be used instead of platinized silver, accompanied with nitric acid, while dilute sulphuric acid accompanies the zinc, the power is 187. A solution of common salt with zinc gives 198. A solution of potash with zinc gives 234.

If coke be used instead of platinum in this same arrangement, and with the same exciting solutions as the last, the power is equal to 225. From these results it will be observed that it will require 3 or 4 pairs of platinized silver, with zinc, and dilute sulphuric acid, to give power equal to one pair, with platinum and zinc, with nitric acid and a solution of potash. Besides, the more power within certain limits, the more available quantity is obtained. This may seem a contradiction to what has been already stated; but, when only one pair is used, there is never obtained that quantity of electricity which the surface of zinc, exposed to the action of the exciting fluid, is capable of giving, owing to its weak power, and the various resistances to its progress; and, in proportion as these resistances are overcome, the quantity increases until there is realised the full amount which the surface of zinc is capable of evolving. The quantity obtained, relative to a given intensity, is of great consequence to the successful prosecution of electro-metallurgy as an art.

The following statement of the proportion of the quantity evolved in proportion to the intensity, in experimenting with various combinations of Daniell's battery, will illustrate our meaning:—

If the decomposing power of 3 pairs be as $1\frac{1}{8}$,
That of 4 pairs is as $3\frac{7}{8}$,
" 5 . . 6
" 10 . . $12\frac{1}{2}$,
" 15 . . $15\frac{3}{4}$,
" 20 . . $17\frac{1}{2}$,

Here it is evident that the increase of quantity diminishes as the intensity increases, until, ultimately, it becomes stationary. It will be observed, too, that in using a Daniell's battery, power may be had economically from 10 pairs and under. Different kinds of battery, differ materially in this respect. The common acid battery such as that above figured, yields an economical quantity with power, with 9 pairs.

Having given an outline of the leading principles of the battery, we shall now return to the processes for making moulds. These may be obtained in various ways. The processes for moulds in fusible metal, wax, stearine, and composition, have already been described in the first volume of this work (p. 186), with the homely but accurate minuteness of practical detail which characterizes Mr. Walker's manual on the subject. We shall here give one or two additional processes, involving the results of our own experience, as well as of the latest improvements:—

A good method of taking moulds is by means of plaster of Paris; the medal to be moulded is prepared with an edge of paper or clay, the face of the mould is oiled thoroughly—so much plaster of Paris as will be thought necessary is put into a basin, which is nearly filled with cold water—care must be taken to disturb as little as possible the mass of plaster at the bottom: it must be allowed to rest while any air bubbles are given off. When they cease to be evolved, pour off all the clear water, and mix the plaster by hand. If any small nodules be found, they ought to be broken by the fingers, though, when the process is carefully conducted, the mass should be free of all small lumps, and the whole will be about the consistence of cream. In this condition, it is poured upon the face of the medal, and allowed to stand till it sets, which may occupy from 15 to 30 minutes—the paper or clay edge is taken off, and the medal may be taken from it by a gentle pull. If the medal be composed of plaster of Paris, which is usually the case, the face of the mould must be prepared to prevent the adhesion of the two plasters. The best substance we have tried for this purpose, is a mixture of soft soap and tallow universally used by potters for preparing their moulds, and called by them *lacquer*. It is prepared in the following manner:—half a pound of soft soap is put into three pints of distilled water, which is set on a clear fire, and is kept in agitation by stirring; when it begins to boil, add from one ounce to an ounce and half of tallow—the whole is then kept boiling till it is reduced in bulk to about two pints, when it is ready for use. The surface of the medal must be washed over with this lacquer, allowing it to absorb as much as it can, when it assumes the appearance of polished marble: it is now prepared with a rim of paper, and the mould taken as directed above. When finished, they will separate easily. If a plaster mould be put into the copper solution, it will be destroyed: this is prevented by saturating or filling up its pores with wax, tallow, or any other substance not acted on by the solution. To do so, the mould is first dried by a moderate heat, and then made sufficiently hot to retain the wax or tallow which is to be applied to it in a melted condition: the tallow or wax is then applied in a melted state, by means of a brush, until the plaster ceases to absorb it: the mould is then allowed to cool gradually, and is now sufficiently protected from the action of the solution. But were it attached to the battery, and immersed into the solution in this state, no deposit would be obtained; because neither the plaster nor the wax is a conductor of electricity. Some substance must now be applied to the surface, in order to give it conducting power; there are several ways of communicating this property, but the best and most simple for articles of the sort under consideration, is to apply common black lead. A copper wire is put round the edge, as in the former moulds, and a little black lead is spread over the surface of the metal, and laid in by a fine brush. The brushing must be continued until all the face round to the wire upon the edge, has a complete metallic polish: a bright polish is necessary to the obtaining of a quick and good deposit. This requires no varnish upon the back, as no deposit will take place where there is no black lead; the mould is now connected by the copper wire to the zinc of the battery, and immersed, when deposition takes place, in the same way as with the fusible alloy: these moulds will seldom do for more than one electrotype. We may remark, that although there may be occasionally a very good electrotype obtained from plaster moulds, still, in general, they are very inferior, as the saturating of the plaster has a tendency to blunt the impression; and if wax has been used for this purpose, it becomes an expensive method, as it cannot be recovered.

The most common material for electrotype moulds, is wax, or a mixture of wax with another substance. Many different mixtures have been recommended; but the best and cheapest in our experience, is a mixture of one part of common bees wax and one of rosin; these are boiled in an iron vessel, over a clear fire; the boiling is continued till all effervescence or frothing ceases, and the mixture is poured out on a flat plate to cool; it is then broken up, and laid past for use.

The directions for applying this mixture both to metallic medals and plaster casts, are the same as those already given for manipulating with stearine and composition moulds in vol. i., p. 186.

Gutta percha is a valuable material for moulding. "We have seen moulds of this substance," says Mr. Napier, "equal, if not superior, to any that we ever saw taken in wax, and of a depth of cutting which it would have been very difficult to have taken in wax." In making moulds of gutta percha it ought to be remarked, that the

manipulation must vary according as the mould is to be taken from metal or from plaster originals. " In making moulds from *metal* originals," says Mr. Walker, " a piece is to be cut from a sheet of gutta percha about the size required; and, after being softened in water at the temperature of 150° or 160°, is to be pressed by screw-pressure, or otherwise, into the medal. *Plaster* originals may be copied most accurately, without undergoing any previous preparation, by the employment of gutta percha, macerated with a little coal naphtha. This preparation is made very plastic by warm water, and does not require much pressure to produce most faithful copies, and without damaging the cast. It is more convenient to purchase it prepared, than to make it."

When an electrotype is required of a model that is undercut, or of a bust or figure, the processes which we have described will not answer, as the mould cannot separate from the model. In such circumstances, the general method of proceeding is to part the mould in separate pieces, and then join these together. The material used for this purpose, is plaster of Paris; the operation, however, to be done well, requires a person of considerable experience. The process which was patented by Mr Parkes, for taking moulds of any kind of models in one piece, is excellently adapted for the electrotypist. It is composed of glue and treacle; 12 lbs of glue is steeped for several hours in as much water as will moisten it thoroughly. This is put into a metallic vessel, which is placed in boiling water, as a hot bath. When the glue falls into a fluid state, 3 lbs. of treacle are added, and the whole is well mixed by stirring. Suppose now that the mould of a small bust is wanted; a cylindrical vessel is chosen, so deep that the bust may stand in it an inch or so under the edge. The inside of this vessel is oiled, a piece of stout paper is pasted upon the bottom of the bust, to prevent the fluid mixture from going inside; and, if composed of plaster, sand is put inside to prevent it from swimming. It is next completely drenched in oil, and placed upright in the vessel; this done, the melted mixture of glue and treacle is poured in till the bust is covered to the depth of an inch. The whole must stand for at least 24 hours, till it is perfectly cool throughout; after which it is taken out by inverting the vessel upon a table, when, of course, the bottom of the bust is presented bare. The mould is now cut, by means of a sharp knife, from the bottom up the back of the bust, to the front of the head. It is next held open by the operator, when an assistant lifts out the bust, and the mould is allowed to reclose; a piece of brown paper is tied round it to keep it firm. The operator has now a complete mould of the bust in one piece; but he cannot treat it like the wax moulds, as its substance is soluble in water, and would be destroyed if put into the solution. A mixture of wax and rosin, with occasionally a little suet, is melted, and allowed to stand till it is on the point of setting, when it is poured carefully into the mould, and left to cool. The mould is then untied and opened up as before, and the wax bust taken out; it may be tied up for other casts. An electrotype mould is now taken from the wax bust, by means of connecting wires, which are fixed upon different parts of the bust, the whole being polished over with black lead, and then connected with the battery, When covered with a sufficient thickness of copper, it is washed from the solution, and the wax melted out leaving a copper mould of the bust, which ought to be well boiled in potash ley. To obtain a fac-simile of the original bust, copper should be deposited inside this mould, which is done by filling the mould with the copper solution, hanging a piece of copper inside this as a pole, taking care that the two do not touch, connecting the copper with the copper of the battery, and the mould with the zinc of the battery, and when the deposit is sufficiently thick, the mould has to be peeled off. It is very difficult to obtain a perfect electrotype by this means. It is much better to cut the mould in two, dividing it along the side, and depositing the copper in the inside of these in the same manner as described for medals, then peeling off the mould and soldering the two halves together.

A mould of a bust may be taken direct from the plaster bust as well as from the wax by saturating the plaster with wax and depositing copper upon it; but it is very difficult to get the plaster out of this mould. It may be sawn in two, and boiled in strong potash for several hours; but there are considerable difficulties attending this. If a bust, whether composed of plaster of Paris, terra cotta, or wax, could get a film of copper immediately deposited all over it by the battery, there would be little occasion for electrotyping copper moulds, as busts of these materials could be made to assume every appearance of a solid copper article. But it is found that covering busts with no other conducting surface than black-lead, preserving also smoothness and proportion, is a very difficult matter. The deposit grows over all the prominent parts, leaving hollow parts such as arm-pits, neck, &c., without any deposit; and when once missed, it requires considerable management to get these parts coated, as the coated parts give a sufficient passage for the current of electricity. It is recommended by some electrotypists to take out the bust, and coat the parts deposited upon with wax, to prevent any further deposit on them; but this practice is not good, especially with plaster of Paris, an electrotype ought never to be taken out till finished. Sometimes the resistance of the hollow parts is occasioned by the solution in these parts becoming exhausted from their position in regard to the positive pole. In this case, a change of position effects a remedy. It may be remarked, that when a bust or any large surface having hollow parts upon it, is to be electrotyped, as many copper connections as possible ought to be made between these parts and the positive pole, or pieces of copper shaped out to fit the hollows are attached to this pole, and brought as near as possible to these parts. If this is carefully attended to, a pretty regular deposit may, with a little attention, be obtained.

All these difficulties have been in a great measure overcome by another patent improvement of Mr Parkes. He prepares the surface with a mixture of sulphuret of carbon and phosphorus, which induces a film of silver or gold upon the surface previously to being put in the sulphate of copper. Thus a complete deposit is instantaneously effected. But we shall extract that part of his patent which refers to the subject. " The solution of phosphorus is prepared by adding to each pound of that substance 15lb. of the bisulphuret or other sulphuret of carbon, and then thoroughly agitating the mixture; this solution is applicable to various uses, and amongst others, to obtaining deposits of metal upon nonmetallic substances, either by combining it with the substances on which it is to be deposited, as in the case of wax, or by coating the surface thereof. Any of the known preparations of wax may be treated in this way; but the one preferred, is composed of from 6 to 8 oz. of the solution, 5lb. of wax, and 5lb. of deer's suet, melted together at a low heat, on account of the inflammable nature of the phosphorus. The article formed by this composition is acted upon by a solution of silver or gold, in the manner hereafter described, with respect to articles which have been coated with the solution.

If the solution is to be applied to the surface of the article, an addition is made to it of one pound of wax or tallow, one pint of spirits of turpentine, and 2 ounces of india-rubber, dissolved with one pound of asphalte in bisulphuret of carbon, for every pound of phosphorus contained in the solution; the wax or tallow being first melted, the solution of india-rubber and asphalte is stirred in; then the turpentine, and after that the solution of phosphorus are added. The solution prepared in this manner is applied to the surfaces of nonmetallic substances, such as wood, flowers, &c., by immersion or brushing; the article is then immersed in a dilute solution of nitrate of silver, or chloride of gold; in a few minutes the surface is covered with a fine film of metal, sufficient to insure a deposit of any required thickness on the article, being connected with any of the electrical apparatus at present employed for coating articles with metal. The solution intended to be used, is prepared by dissolving four ounces of silver in nitric acid, and afterwards diluting the same with twelve gallons of water; the gold solution is formed by dissolving one ounce of gold in nitro-muriatic acid, and then diluting it with ten gallons of water."

We have frequently repeated these operations described by Mr Parkes, to our entire satisfaction, and we were enabled to cover every variety of surface with as much rapidity as if the article had been wholly composed of metal. The solutions of silver or gold prepared will last for a long time; that of gold, where it can be obtained, is much superior to that of silver. A bust, or figure, prepared according to any of these processes, may be covered with copper to the thickness of stout paper, without distorting the proportions of the figure, and is perfectly smooth. The principal use of making copper moulds of figures from the elastic moulding, is not to make fac-similes in copper, but to make figures of solid silver. Copies of highly wrought work,

either chased or engraved; or of articles, duplicates of which cannot be obtained, or of which the workmanship may have been costly, may, by this means, be made in solid silver, at little more expense than the cost of the metal. Our next business will be to describe the processes for silver and other solutions.

EXPERIMENTS AND EXPERIMENTING.

Experience is justly considered the great and ultimate source of all physical knowledge—the fountain of all applicate science. The truths which it develops stand forth as the elements of the gigantic superstructure of art and industry which skill and ingenuity have erected as the bulwark of modern civilization. Annihilate experience; and, although left in possession of a code of abstract science, more extensive and more complete than has yet been framed by the aggregate intelligence of all generations in all ages, our condition would be that of utter helplessness. Proceeding from those simple notions of space, form, and number, which constitute the inseparable moduli of thought, we might reason out for ourselves all the truths of mathematics, and ascend to the noblest conceptions of the beautiful and sublime; but it would be impossible to predict the consequences of stepping over a precipice, or the effect which would be produced on the eye by mixing the colours blue and yellow. Without physical data, without the facts and revelations of experience, our reasonings would be inane, shrivelled, and shadowy,—mere phantasms, like the ghosts on the banks of the Styx wandering in search of a body, in which they might find a "local habitation and a name." It is from this state of *no-being* that experience, dispassionately reasoned on and methodized, has enabled us to ascend to that stage of excellence in the arts of civilized life, which has placed the present age without a parallel in the world's history.

But experience, although the assignable coefficient of all our progress in the arts, and all our advancement in science, is not itself a simple quantity—it is the sum of our passive and active observation. In the first term we include all facts which spontaneously present themselves to our notice, and in which there is no attempt made to vary the circumstances under which they are observed, or to influence the frequency of their occurrence. To this we may refer as the great fountain of that every-day knowledge which we involuntarily and unconsciously practise, and of which we cannot divest ourselves, without ceasing to think and to live. But this broken and imperfect experience of itself carries us only a short way beyond the attainment of that modicum of knowledge which is absolutely requisite to the human being in his lowest condition, to enable him, under ordinary circumstances, to provide for the wants and cravings of his animal constitution. For the attainment of higher purposes, our experience must be active. It is not enough that we note the facts and phenomena as they accidentally present themselves—we must search for them patiently and perseveringly. We must learn the language in which Nature has transcribed her laws; and, bringing into action causes and agents over which we have control, we must vary their combinations, and compare and classify the results as they arise, compare one part of the evidence with another, cross-examine our witnesses, and note, without prejudice or preconceived opinion, the nicer shades of meaning conveyed in their responses. From this process we derive something more than vulgar experience. The facts which it brings to light lie deeper, are better defined; and, being evolved in juxtaposition, their relations are traced with greater exactness and more certainty, than if they had been derived piecemeal from partial and accidental observation of spontaneous phenomena. This systematic searching for experience by direct interrogation of Nature constitutes *experiment*—the foundation of all exact physical knowledge and of all its practical applications.

In experimental research, we may not always be successful in discriminating truth; but in the attempt there is gain. The alchemist found not the philosopher's stone in his crucibles; but he found something of higher value—he found chemistry. It is one peculiarity of physical research, and not the least of the many inducements there are to stimulate to investigation, that every new step, judiciously advanced, conduces to the establishment of the general proposition—the Baconian principle—that all natural science is but a series of inductive generalizations—of facts reasoned upon and generalized, commencing with the most circumstantial particulars, and carried up to universal laws which comprehend in their statements every subordinate degree of generality. In this we must include the inverted reasoning from generals to particulars, by which those general principles are traced back to their remotest consequences, and all particular propositions deduced from them. In this descent we necessarily encounter—though we may not always observe—all those facts on which the arts and processes that tend to the accommodation of human life depend, and obtain thereby the disposal of the powers of nature, co-extensive with our accuracy of observation, and correctness of deduction. All science is thus the offspring of experience and experiment—experience methodized; and art, being the application of knowledge to practice, claims no higher parentage. If the knowledge be crude—a conglomerate mass of undigested facts—the art which is founded upon it is empirical and stationary; it must wait for the agitating of the waters to infuse life and spirit into its operations, to sift it of its technicalities and its mysteries; but if it be the corollary of experience reasoned upon, and systematized, it assumes a higher character and a higher degree of development; it is scientific art varying in excellence and approaching perfection, as the principles upon which it is based become more fully understood and recognised in its practice. It is to the archive of experiments, successful and unsuccessful, and gradually accumulating, that we must look for a solution of the various problems that arise in the exercise of the arts of life, and in the gratification of that desire inherent in the human mind, to penetrate deeper and deeper into the arcana of nature's operations. It is to the same code of evidence that we must have recourse for explanation, when we would deviate from established practice, and invade received opinion.

But in appealing to recorded experiment as the groundwork of practice, it must not be overlooked, that fallacy not unfrequently assumes the garb of truth. Nature is ever true, and the laws of nature are perfect; but man may fail in the interpretation. That there are more false facts than false theories in the world, is a saying not less true than trite. The reason is not difficult to find; the correctness of a fact—rather the correctness of a statement—is totally dependent on the capacity, the intelligence, of the observer; and it is no common acquirement, no mean evidence of perspicacity, to be able to discern aright. In the common concerns of life, how many false notions obtain credence, and how seemingly few there are exempt from the common danger of embracing fallacy for truth. Limited intelligence must ever be prone to error; and where the mind is not trained to habits of thought and discrimination, the liability to misconception and erroneous deduction is doubly augmented. At first sight it may appear a pre-eminently easy matter to observe the facts and circumstances developed in cases of direct interrogation of physical agencies. But the mass of confusion which prevails on many important topics of a scientific character, bear ample testimony to the want of accuracy in observation, and the consequent want of accuracy in the conclusions deduced. Nature's responses are unerring, and her language is perfect; but the interrogation may be too limited, too circumscribed, possessing too little perspicuity, to elicit more than a partial enunciation, where a full revelation was expected. It is this mistaking of a part for the whole,—this misconception of the strict meaning of physical language,—this haste of interpretation—to which we are to attribute the confliction of opinion entertained on subjects of science and scientific inquiry, and the want of unity in the essential data embodied in the discussion. It would be far from desirable to check discussion and stifle opinion; but, unfortunately for the advancement of accurate

knowledge, we are more prone to build up theories, than to collate, analyse, and register facts. Truthfulness is our aim and object: it is our creed in science and in practice; but we do not uncommonly overlook the circumstance, that in all philosophy, a perfect theory is the result of the perfection of the science. To assume the converse—that the perfection of science results from the theory—is in effect to contradict the meaning of established language, to retrograde from the nineteenth to the sixteenth century, to repudiate the Baconian philosophy, and deny the inspiration of the Novum Organum.

The qualifications necessary to conduct successfully an experimental inquiry of much depth, are not gifts of common occurrence; they belong to an order of mind in which comprehensive and penetrating intelligence, keen and accurate perception of relations, much fertility of invention, much ingenuity and bold conception, are combined with unflagging perseverance, and extensive knowledge of all collateral experience. Thus qualified, the experimenter must lay aside prejudice and preconceived notions; he must enter Nature's temple with a full knowledge and well-grounded conviction of his own worthiness to approach the altar of the ever-living, all-embracing spirit of physical truth. He must have full assurance of his mission—must stand in the sacrarium of science—before the oracle-seat of Nature's laws, with single purpose and a good conscience. Acquainted with the language and symbols in which the truths of science are written, his sacred business is to seize upon the revelations which offer, and in a word-for-word translation, enter them upon the records of written experience. If he refuse this—if he think the occupation too scrivener-like—too mechanical—if he set himself to accommodate the language of the oracle to a particular theory, hypothesis, or creed; and if, mistaking a Pythian afflatus for inspiration, and pretension for genius, he enter the temple of truth and make a show of worship, that he may get himself a name and notoriety by the promulgation of many-coloured notions, flaunty and meaningless—he is incapable of science, unworthy of trust as an experimentalist, and to be rejected as an authority in matters of interpretation of physical truth.

In reviewing the history of the applications of mechanical science, we encounter numerous examples illustrative of the patient truth-seeking spirit which ought to animate the experimenter; the subjects embraced include the whole range of practical mechanics, and the aggregate of experimental research is correspondingly extensive. Much of it is indeed wanting in the all-requisite quality of accuracy; some part is deficient in comprehensiveness of detail and purpose; and more of it is vitiated by defective modes, erroneous assumptions, misconception and misinterpretation of results. Hence the contradictions, the confusion, and want of unity and perspicuity, which prevail in respect of subjects of the most common kind and character. Let us take a familiar instance—the dynamical efficiency of men and horses. This is a subject within the comprehension of almost the "meanest capacity," and one which at first sight might seem to require no talent, little ingenuity, and no large amount of *tact*, for its investigation. The question has at length been solved with sufficient exactness for all practical ends; but the solution has only been obtained by an amount of experimental inquiry, extending over a period of a century and a half, and conducted by men of recognised talent, learning, and honesty. Among the older investigators, we find the names of De la Hire and Amontons: the one considered the question almost exclusively with reference to the muscular power of animals, and the other with reference to their velocity. Next of note is Deparcieux, who conceived that the problem involved both weight and muscular action conjointly. He is followed by Lambert, who endeavoured to include in a general equation, the relation between the weight, velocity, burden, and path of inclination, pursued by the animal. The celebrated Bernouilli maintained that the quantity of fatigue is always proportional to the quantity of action, a proposition which Coulomb proved to be absurd, by showing that the daily quantity of action varies with the circumstances under which it is developed. The estimates of Desaguiliers and Emerson were founded on partial data; and the experiments of Smeaton and Watt were too limited in their purpose, and furnished only a rough approximation to a solution of the question. The investigations by Schulze in Germany, and Buchanan in Scotland, went far to establish the standards of value of the mean and absolute effect of human labour: but it has only been by the united researches of Fourier, Morin, Devillers and Gerstner, on the continent; and of Tredgold, Palmer, Silvester, Bevan, M'Neill, Field, and Rennie in England, that we have arrived at a trustworthy solution of the general problem. The solution, even yet, remains to be put into a convenient practical form; and he who shall analyze, collate, methodize, and concentrate the data, and extend the results by a fair comparison and honest interpretation, shall render essential service to the engineer, and deserve a higher meed of approbation than will probably be awarded him.

In this example we may observe the gradual enlargement of the views entertained of the final objects to be accomplished, and of the conditions involved in the question. Of the varied circumstances necessary to be taken into account, we observe them one after another discovered, included as elements of the problem, till ultimately the whole variety of action, and every mode of its application and development, were brought under the cognisance of observation, comparison, and calculation. The problem was besides difficult, on account of the multiplicity of results obtained by examination of particular cases, influenced by all the variable circumstances which may be supposed to affect the degree of action in agents so different among themselves, and so perceptibly affected in dynamical efficiency, by every little modification under which their power is exercised. The problem, having respect to the average mean and extreme effective powers, could not be satisfied by a few partial results, however accurately deduced. Its conditions were general and mixed, and deeply and widely involved. Ascending from individuals to aggregates, from stationary labour in all positions to labour at maximum velocity, it aimed at the establishment of a standard unit of effective power, which, in all times and under all circumstances, might be taken as a safe basis of calculation in estimating the amount of labouring force necessary to effect a given purpose in a given time, and to which other labouring force might be intelligibly referred. The question, therefore, although requiring no talent of a high order, no great perspicacity, little inventive genius, was yet in reality one of much intricacy, requiring much patient observation, and much varied experience—and experience which could only be obtained at distant intervals and fitting opportunities. It is consequently not a matter of surprise that it was by a long and tedious route that an appropriate solution was arrived at, and finally recognised.

Although in this example the experimental investigation has been crowned with success—not that we conceive it to be incapable of further illustration, but that for most practical purposes the data obtained may be employed with confidence—it is not to be assumed that every branch of physical inquiry which has occupied a like amount of attention, has attained the same degree of completeness. On the contrary, there are several departments in which our knowledge can hardly be said to have advanced beyond the threshold—which have in fact baffled all attempts to establish any certain data for practice, or any fixed law of combination. Even at this moment, we have no positive assurance that we thoroughly understand the physical properties of iron, and the theory of torsion remains where Coulomb left it. In hydraulics, we have much to learn and much still to investigate. Even the motion of a vessel through the water—a subject of general interest and of the utmost national importance—is a problem still to be solved. It is true we have well built and fast sailing ships, but we have ships also which seem to have been built rather for being packed in docks than for sailing. This indeed may be regarded in some degree as the effects of prejudice, and still more as the result of an erroneous practice, in some measure made necessary by the old mode

of tonnage measurement, than of absolute ignorance of the form and figure best adapted for locomotion on the surface of the liquid element. Still, the science of the subject has its difficulties; and notwithstanding that few, if any, of the abstract principles involved in the theory have been left uninvestigated, there are still questions of importance which have not found appropriate answers in practice. This is not surprising; the conditions are not definite but relative, and depend in some part upon elementary principles, of which our knowledge is imperfect.

To render this apparent, it may be necessary to refer to the fundamental conditions of the problem—the form of least resistance, combined with capacity and the requisite sailing qualities adequate to the circumstances of a rough sea and oblique winds. But the determination of the form involves the general solution of the problem of the resistance of fluids—a subject which has baffled alike the researches of the mathematician and the experimentalist. Colonel Beaufoy expended £30,000 of government money, in attempting to determine the form of least resistance, with a view to the establishment of a principle in the practice of ship-building; and Mr. J. Scott Russell expended a considerable sum of money belonging to the British Association, ostensibly in the same pursuit. Both have signally failed of success. In the hands of the mathematician, the experiments of Beaufoy may indeed be yet made available as data on which he may try the force and efficiency of his formulæ; but for ship-building purposes they are destitute of value. Mr. Russell's investigations were equally unproductive of settled principles. Let us, for instance, peruse the following brief extract from one of the reports submitted by him to the Association:—

"To show how much influence *form* alone, without any other element or dimension, affects the question of resistance, four vessels were taken, having all the same length, the same breadth, the same depth, the same area and form of midship section, and all loaded to the same weight, displacement, and draft of water; the only difference being in the character of the water-lines; No. 1 being of the new form indicated by these experiments as that of least resistance; No. 3, the old form very near the reverse of the first; No. 2, intermediate between them; and No. 4, intermediate between No. 1 and No. 2. The following table shows the result of the comparative trial:—

Speed in miles per hour.	Resistance, in pounds.			
	No. 1.	No. 2.	No. 3.	No. 4.
3 miles.	10	12	12	11·3
4 ..	18	22	23	21
5 ..	28	38	42	35
6 ..	39	61	72	56
7 ..	52	96	129	84

These differences showed how much might be gained, every thing else being equal, by the adoption simply of judicious form in the construction of the water-lines of a ship. The vessel No. 1, was constructed on the wave-line."

But Mr Russell's experiments were unfortunately undertaken and conducted under circumstances, by no means favourable to accuracy of observation, and independency of conclusion; encumbered by the perplexities of his "wave-line" hypothesis, the results obtained, necessarily took the co-ordinate character of its sinuosities. This is more than borne out by the circumstances of the experiment above described; and that experiment, we may observe, is the only one of all the vast number reported to the British Association, having the most distant promise of utility. In that experiment there were four boats employed, in every respect alike except in form; and, referring to the table, it would appear that each boat required a particular amount of tractive force, varying with the character of the water-line, to make it pass through the water at a given velocity. This looks well in a report; but the facts of the experiment are slightly different. It is true four boats were employed, and four different results were obtained; but it is also true, that two of these boats were precisely alike—were built to the same lines; and when submitted to trial, had all the similarity which the same builder and the same quality of material could give them. This was accidental we admit, and unknown to Mr Russell, and the fact, perhaps, cannot be verified by reference to the actual boats employed. These were intended as quarterboats for the West India steamers, but at the conclusion of the experiment all the four were swamped, and two of them only were recovered;—the statement, however, is strictly correct, and affords us a very excellent illustration of the confidence to be placed in experiments conducted for the purpose of maintaining an assumed position.

But although Colonel Beaufoy and Mr Russell have done nothing to advance our knowledge of the theory of fluid resistance, we may yet safely conclude, from the analogy of discoveries in other sciences, that even its difficulties must yield to the patient investigation of the inductive philosopher. In the mean time there is no cause for despondency. We may not have attained to that degree of knowledge necessary to "effect with precision and confidence, the synthetical composition of a perfect ship;" but we have arrived at that point from which, "by the application of principles already established, we may proceed in the full confidence of producing one with a preponderance of good qualities. The mistake commonly committed is in the assumption, that the theory of ships is already perfect, instead of merely being capable of being perfected by a rigid analysis of facts, which daily experience would elicit, were the abstract sciences applied to the task of analyzing, collating, and registering them."—*Creuze.*

Water-wheels were long a favourite subject of experiment, and it is only of late years that the principles involved have been established on a proper basis by the researches of Poncelet, and of the Committee of the Franklin Institute. Smeaton's experiments, so often still appealed to, like those of Pitot, Borda, Bossut, Eytelwien, and Morosi, on the Continent—and Robison, Fenwick, Banks, and Buchanan, in this country—had the great defect of being made upon too small a scale to be useful as practical data. The further experiments of Navier and Morin in France, and of Rennie and Mallet in England, have supplied what was wanting in variety of circumstance and detail in the preceding investigations, and may be regarded as the final settlement of the question in respect of vertical wheels.

We have indeed hardly any better example of careful experimental research on record, than the experiments upon water-wheels by M. Morin, unless it be his admirably conducted experiments upon friction. In these last, we find the solution of a question which had baffled the ingenuity of all previous experimentalists, Coulomb among others; and, observing the skilful arrangements and precautions to ensure accuracy; the consummate ingenuity manifested in the contrivances for measuring the results; the full, clear, and circumstantial detail of the various contrivances employed, and the results obtained, and the clear and accurate conclusions deduced; it is impossible not to yield to them our utmost confidence.

We might refer to many other experimental investigations, good, bad, and indifferent, successful and unsuccessful, but as we intend to return to the subject, *occasione datâ*, it may be enough briefly to remark, that the grand object to be aimed at in researches of the kind, is accuracy of observation. This, accompanied with complete details of the means employed, the precautions taken to ensure exactness in the results, and the nature of the apparatus employed, are elements essentially requisite to inspire confidence and give a value to the conclusions arrived at. A single flaw, a single omission, neglect, or oversight, destroys confidence, and renders the whole investigation worthless. Much labour may thus be expended for no purpose, and the more expensive the experiments, the more ridiculous does the experimenter appear. There is no sympathy for failure—no excuse for error—no allowance for false conclusion. No amount of good

intention can be admitted in extenuation of an illogical deduction; the search is for truth: with that, everything; without it, nothing. Every attempt to impose the *truth-like* in its stead, is a fraud which its worshippers will not and dare not forgive.

GEOLOGY

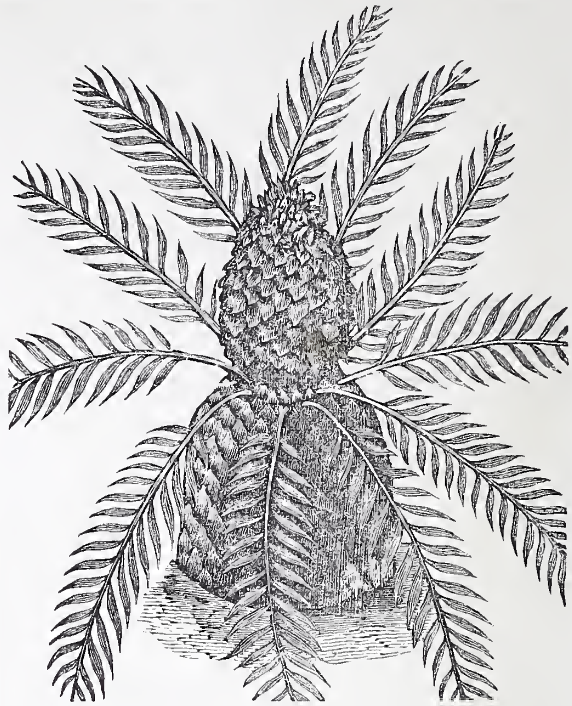
CHAPTER XVII.

THE OOLITIC SYSTEM—*continued.*

Organic Remains.—In our last, we introduced the reader to those strange, and, in some instances, monstrous saurians which existed in the secondary periods. The conditions under which the more ancient forms of saurian existence lived, were doubtless analogous to those which characterize the habitats of the recent species; namely, the proximity of large rivers, and the existence of a tropical temperature. The recent crocodiles and large lizards are all inhabitants of tropical countries, as are also the natural order of turtles, a family also exceedingly developed in the oolitic period, no less than twenty species of emys (fresh-water turtles) having been discovered in the Jura formation, near Soleure alone. The presence of many sponges, and of the beautiful radiata, particularly the cidaris, which is so analogous to existing tropical species, are all in confirmation of the important fact, that, to whatever cause it may be attributed, the climate of these latitudes was much more akin to that of the torrid zone, than to that which we now enjoy; and this is still more confirmed when we contemplate the character of the fossil plants which occur in these formations, the most characteristic of which is the Cycadean family, the stems and leaves of which show considerable analogy to the existing forms of that tribe at the Cape of Good Hope, and in India and Australia. The shores of Australia still nourish the trigonia, cerethium, and the isocardia among the shell-fishes, and the zamia and the

Cycas.

fern tree among the plants; all of which congeners are met with in the oolitic rocks. And this analogy between the Australian and the tropical forms would be still more confirmed, were the fossil jaws found in the oolitic slate of Stonesfield fully determined as belonging to animals of the Marsupial tribe, so characteristic of the zoology of New Holland.



Zamia.

Brongniart describes about 70 species of land plants, as occurring in secondary strata; the half of these are coniferæ, or pine-bearing plants, and cycadites, plants intermediate in structure with palms, tree ferns, and the pines. Of the one-half, 29 are cycadites, the remaining half ferns, equisetæ, and lycopodiums. The predominance of cycadeæ and coniferæ in the secondary era, over other forms, is highly illustrated by the fact, that they form one-half of the numerical amount of its vegetation, whereas, in the existing order of nature, they compose only about a one-three-hundredth part of living plants.

The cycadeæ consist of two genera, the cycas and the zamia. Of the former genus, there are 5 known species, and 17 of the latter. Not a single species of the cycadeæ grows at the present time in Europe: their principal localities are parts of equinoctial America, the West Indies, the Cape of Good Hope, Madagascar, India, the Molucca Islands, Japan, China, and New Holland. Four or five genera and twenty-nine species of cycadeæ occur in the fossil Flora of the secondary periods; but the remains of this family are very rare in the rocks of an older or later date. Count Sternberg, in a letter to Dr. Buckland, mentions that he has found both the cycas and the zamia in the coal formation, but this is the only instance on record of such an occurrence; and it is not impossible, notwithstanding the high authority of Count Sternberg, that a mistake as to the true nature of the coal fossils may have taken place, as certainly some of the leaves of the flabellaria are not unlike those of the cycadeæ. The most abundant deposit of the leaves of this last class of plants is the oolitic formation on the coast of Yorkshire, between Whitby and Scarborough—they are also found in oolitic slate of Stonesfield, in Oxfordshire. The genus Pterophyllum (wing-leaved) is found from the red sandstone to the Wealden formation; and figures of cones which Lindley and Hutton consider referrible to the genus zamia, are found in the Wealden formation on the south coast of the Isle of Wight.

This family of plants, so interesting from its prevalence during a long epoch of geological time, forms one of the

natural orders of gymnospermous, or naked-seeded plants. "It is essentially characterized by its trunk growing in a cylindrical, unbranched manner, in consequence of the development of one terminal bud only, and of its diœcious (1) flowers, of which the males at least grow in cones composed of its peltate (largest sloped) leaves. In the genus zamia, the female flowers are also disposed in the same manner; in the other, cycas, they are placed upon the toothings of the absolute leaves, occupying the centre of the terminal bud. The leaves of these plants are pinnated (winged) and have a certain resemblance to ferns and palms; the wood of both is arranged in concentric circles, which in the cycas are numerous, and in a confused manner about the central pith, so that a cycadaceous plant partakes in structure of the peculiarities of both exogens (2) and endogens (3). In the manner in which their leaves enroll, and in their terminal single bud, the cycadeæ resemble ferns, with which they may, moreover, be compared on account of their proceeding from leaves. With coniferæ they accord in the cone-like arrangement of their parts of fructification, and their naked ovules, (seed vessels,) and with the palms in the secretion of a large quantity of fæcula (excrementitious matter) in their stem, in their mode of growth, and in the arrangement of a part of their woody system. Cycadeæ, therefore, belonging, as they do, to gymnosperms (4), possess nearly equal affinity with palms or endogens, and fern trees or acrogens" (5).—*Penny Cyclopædia.*

The characters above enumerated are found in the fossils as well as the living varieties, both exhibiting an internal structure of the trunk, containing a radiating circle or circles of woody fibre, imbedded in cellular tissue; and their outer case being composed of petioles in place of a bark, as also by their mode of increase by buds protruded from germs in the axillæ (6) of the petioles (7).

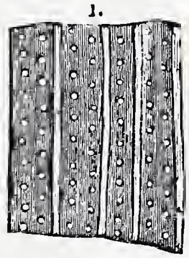
"However remote," says Dr. Buckland, "may have been the time when these prototypes of the family of the cycadeæ ceased to exist, the fact of their containing so many combinations of peculiarities identical with those of existing cycadeæ, connects these ancient arrangements in the physiology of fossil botany, with those which now characterize one of the most remarkable families amongst existing plants. In virtue of their peculiar structure, the living cycadeæ form an important link which no other tribe of plants supplies, connecting the great family of the coniferæ with the families of palms and ferns, and thus fill up a blank which would otherwise separate these three great natural divisions of dicotyledonous, monocotyledonous, and acotyledonous plants. The full development of this link, in the secondary periods of geological history, affords an important evidence of the uniformity of design which now prevades, and ever has pervaded, all the laws of vegetable life. Facts like these are inestimably precious to the natural theologian; for they identify, as it were, the Artificer, by details of manipulation throughout his works. They appeal to the physiologists in language more commanding than human eloquence; the voice of very stocks and stones, that have been buried for countless ages in the deep recesses of the earth, proclaiming the universal agency of one all-directing, all-sustaining Creator, in whose will and power those harmonious systems originated, and by whose universal providence they are and have at all times been maintained."

Fragments and trunks of coniferous wood are common to the coal formation, and to the secondary rocks of which we have been treating. They are also found in the tertiary formations. These last approximate much more nearly to the structure of existing genera than those found in the secondary beds.

The coniferous trees, however, of the transition and secondary eras, show both the structure of ordinary pines and that of the Araucaria; though the latter predominates in the fossil wood found so abundantly in the lias formation near Whitby, the vegetation of which is singularly allied to that of the southern hemisphere of the present day. Only four existing species of the Araucaria are known; one belongs to the east coast of New Holland; another to Norfolk island; a third to Brazil; and a fourth to China.

We are indebted to microscopical observations made on the recent woods of coniferous plants, and on the fossil remains alluded to, for the discovery of their analogies. When so examined, coniferous wood is found to be arranged in vertical rows of discs either singly or in pairs. When double rows occur, the discs of both rows are placed side by side, and never alternate, and the number of the rows of discs is never more than two; whereas, in the araucaria, the group of discs is arranged in single, double, triple, and sometimes quadruple rows. They are much smaller than those of the true pine, scarcely half their size; and in the double rows, they always *alternate* with each other, and are sometimes circular, but mostly polygonal. Mr. Nicol has detected a row of not less than fifty discs in the length of the twentieth part of an inch, the diameter of each disc not exceeding the thousandth part of an inch; but even the smallest of these are of enormous size compared with the fibres of the partitions bounding the vessels in which they occur.

1.



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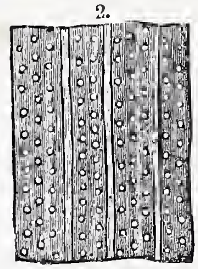


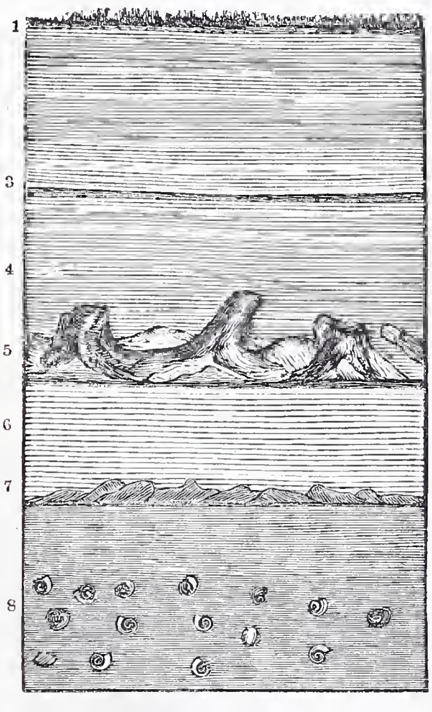
1. Structure of the common pine wood. 2. Structure of the wood of the Araucaria pines.

The oolitic quarries of Portland have been long remarkable for their containing certain strata called the "dirt-beds," in which the stems and branches of coniferous trees and cycadeæ are found in considerable abundance. Many of the trees as well as the plants are still erect, with their roots ramified in the dirt-beds, which appears to be the soil in which they grew. "On my visit," says Mr. Mantell, "to the island, in the summer of 1832, the surface of a large area of the dirt-bed was cleared, preparatory to its removal, and a most striking phenomenon was presented to my view. The floor of the quarry was literally strewn with fossil wood, and I saw before me a petrified tropical forest; the trees and plants like the inhabitants of the Alg, in the Arabian story, being converted into stone, yet still maintaining the place which they occupied when alive! Some of the trunks were surrounded by a conical mound of calcareous matter, which had evidently once been earth, and had accumulated around the base and roots of the trees. The stems were generally three or four feet high, their summits being jagged and splintered, as if they had been torn and wrenched off by a *hurricane*—an appearance which many trees in this neighbourhood, (Bristol,) after the late storm strikingly resembled. Some of the trunks were two feet in diameter, and the united fragments of one tree measured upwards of thirty feet in length; in other specimens, branches were attached to the stem. In the dirt-bed there were many trunks lying prostrate, and fragments of branches. The fossil plants are called cycadeodia by Dr. Buckland, from their analogy to the recent cycas and zamia, but for which M. Adolphe Brongniart has established a new genus, named Mantellia. The plants occurred at intervals between the trees, and the dirt-bed was so little consolidated, that I dug up with a spade, as from a parterre, several specimens that must have been on the very spot on which they grew, like the columns of Puzzioli, preserved erect amidst all the revolutions which the surface of the earth has subsequently undergone, and beneath the accumulated spoils of ages. The trees and plants are completely petrified by silex or flint."

From what has been stated, it is evident, that after the marine strata, forming the base of the isle of Portland, were deposited at the bottom of a deep sea, and had become con-

solidated, the bed of that ancient ocean was elevated above the level of the waters, became dry land, and was covered by forests. How long this new country existed cannot be now ascertained; but that it flourished for a considerable period is certain, from the number and magnitude of the trees of the petrified forest. In the isle of Purbeck, traces of the dirt-bed, with trunks of trees, are seen beneath the fresh-water limestones of the Weald ; a proof that, before the deposition of the Purbeck marble could have taken place, the petrified forest must have sunk to the depth of many hundred feet.

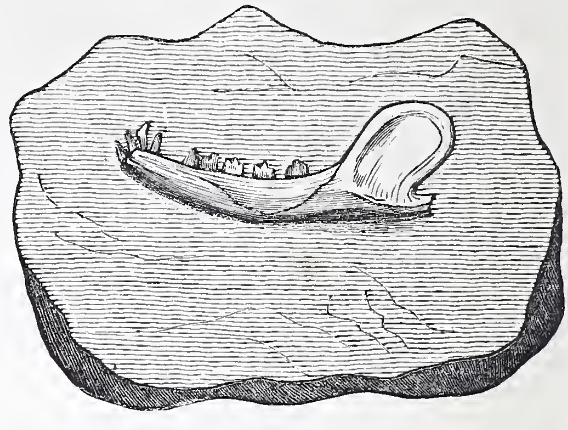
Space will not permit us to describe the other varieties of the vegetable kingdom which occur in secondary strata; it must therefore suffice to observe, that, like their contemporary animals, they are all more or less indicative of a much higher temperature than is now enjoyed in the latitudes in which they occur. For example, a beautiful and unique fossil fruit, allied to the Pandaneæ or screw pines, which grow only in the warmer zones, and chiefly within the influence of the sea, was found by the late Mr. Page, of Bishport, near Bristol, in the lower region of the inferior oolite formation on the east of Charmouth, Dorset, and is now in the Oxford museum. The size of this fruit is that of a large orange. "We have as yet," says Dr. Buckland, "discovered no remains of the leaves, or trunk of Pandaneæ in a fossil state, but the presence of our unique fruit in the inferior oolite formation near Charmouth, carries us back to a point of time, when we know from other evidence that England was in a state of new-born land, emerging from the seas of a tepid climate; and shows that combinations of vegetable structure, such as exist in the modern Pandaneæ, adapted, in a peculiar manner, to the office of vegetable colonization, prevailed also at the time



1. Vegetable soil. 2, 4, and 6. Fresh water limestone 3. Clay. 5 and 7 Dirt-bed, with cycadites, &c. 8. Portland oolite, containing marine shells, &c.

when the oolite rocks were in process of formation. This fruit also adds a new link to the chain of evidence, which makes known to us the flora of the secondary periods of geology, and therein discloses fresh proofs of order and harmony, and of adaptation of peculiar means to peculiar ends; extending backwards from the actual condition of our planet through the manifold stages of change, which its ancient surface has undergone."

The occurrence of two or three fossil jaws in the oolitic slate of Stonesfield, which Baron Cuvier pronounced to have belonged to a mammiferous (8) quadruped of the marsupial (9)tribe, has led to much discussion and no small difference of opinion among comparative anatomists, whether it ought to be regarded as belonging to a mammiferous animal or not.



Lower jaw of Didelphis, or Phascolotherium Bucklandi.

For an account of this discussion, and an elucidation of the views of Professor Owen and others on the subject, we must refer our readers to a long and very learned article in the 14th volume of the *Penny Cyclopedia.*

Molar tooth magnified ten times.

In a paper read before the Geological Society, on the Structure and Relations of the Presumed Marsupial Remains from the Stonesfield Oolite, by Mr. Ogilby, after a deal of reasoning as to the correctness of Cuvier and Owen's conclusions, the author judiciously remarks, that the fossils present so many important and distinctive characters, in common with mammals on the one hand, and cold-blooded animals on the other, that he does not think naturalists are justified at present in pronouncing definitely to which class the fossils really do belong.

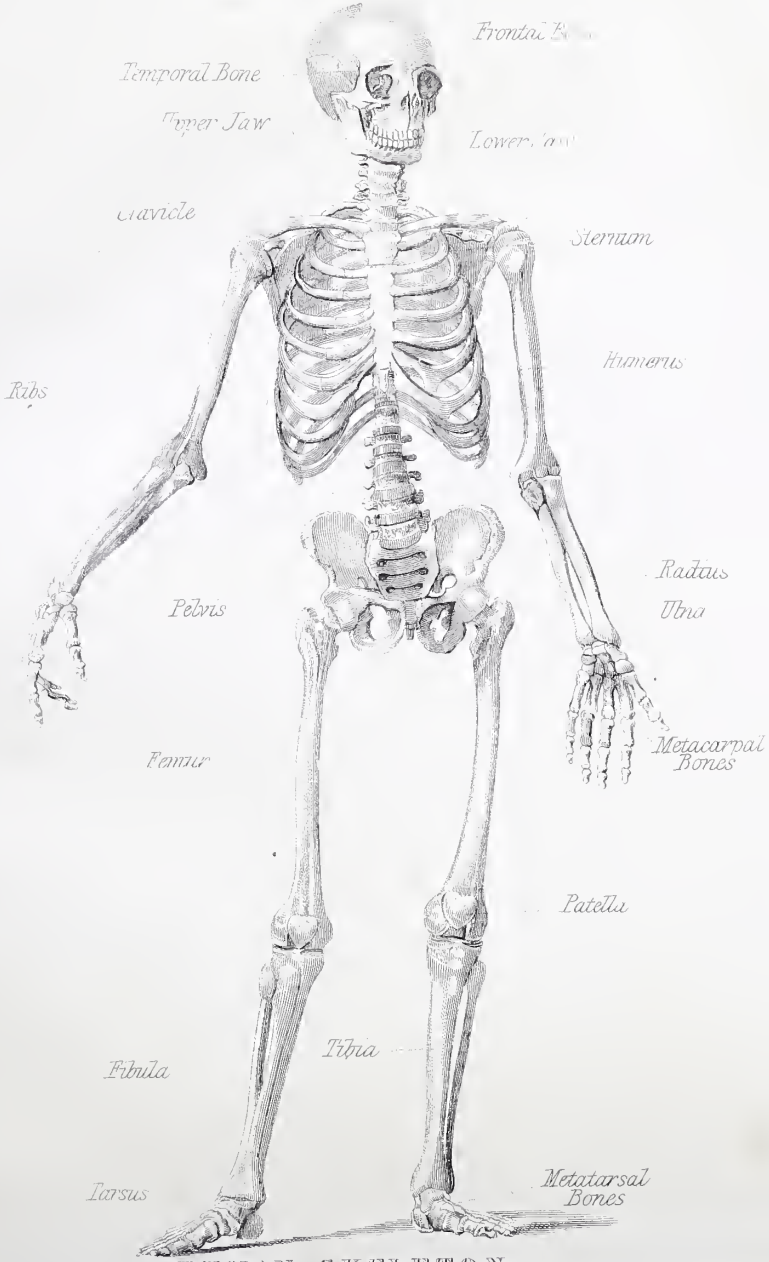
The annexed figure is a drawing of one of the jaws in question.

Did these remains belong to extinct marsupials (pouched animals), they present a very strange anomaly in the history of the earth, viz., that of the existence of a single genus of the most important division of the animal kingdom, as the first mammifers, and the only warm-blooded quadrupeds called into existence before the termination of the chalk period, and the introduction of existing species of marine mollusca.

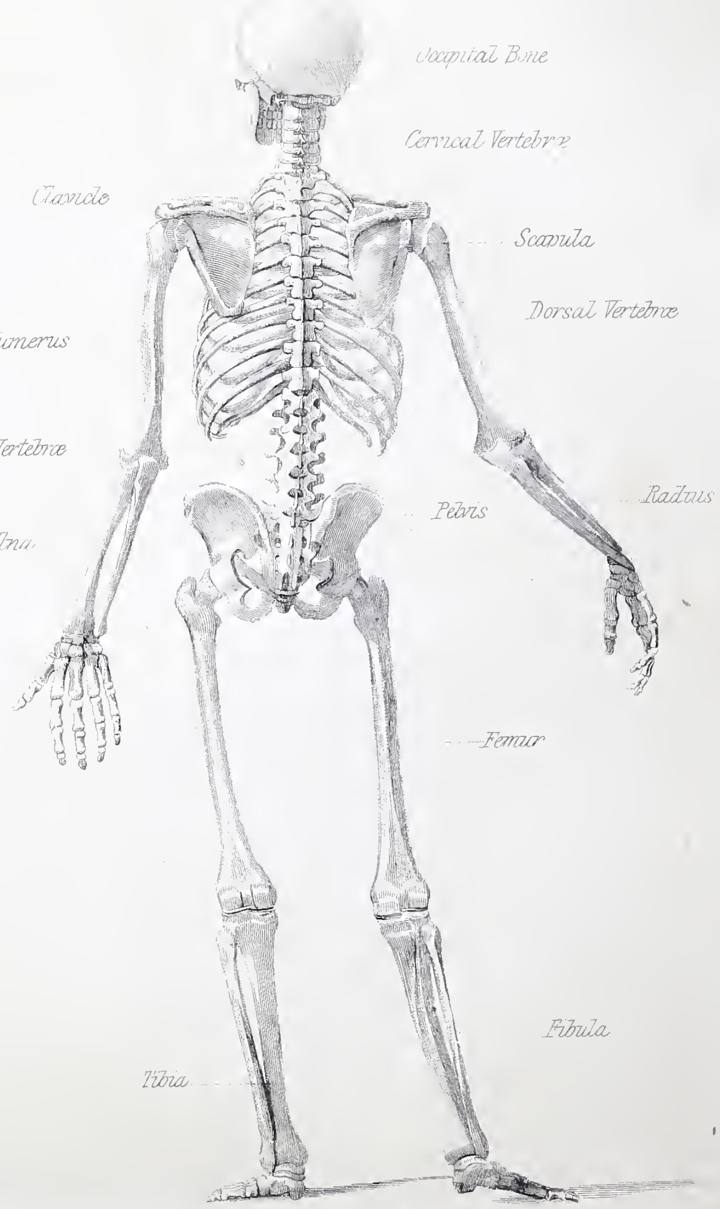
In our next, we shall, in treating of the chalk formation, bring under review the character of the peculiar mollusca which existed in the seas, lakes, and estuaries of the secondary period.

*** 1. *Diœcious*, applied to plants which have the stamens on one plant and the pistils on another. 2. *Exogens*, plants which increase in diameter by the addition of new wood to the outside of the old tree. Examples: the oak, beach, fir. 3. *Endogens*, plants which increase in diameter by addition to its centre. Example: the palm tree. 4. *Gymnosperms*, plants which, like the firs, have seeds not enclosed in a pericarp or seed-shell. 5. *Acrogens*, plants which grow at their ends only without increasing in diameter. Examples: ferns, and all flowerless plants 6. *Axillæ*, the acute angles formed by the junction of the leaves to its axis or stem. 7. *Petioles*, the stalks of leaves. 8. Mammiferous, from *mammæ*, paps, and *fero*, I carry, applied to all animals that suckle their young. 9. *Marsupial*, applied to animals which, like the opossum or kangaroo, have a bag or pouch attached to their belly, in which they carry their young.

ANATOMY & PHYSIOLOGY.



HUMAN SKELETON



HUMAN SKELETON

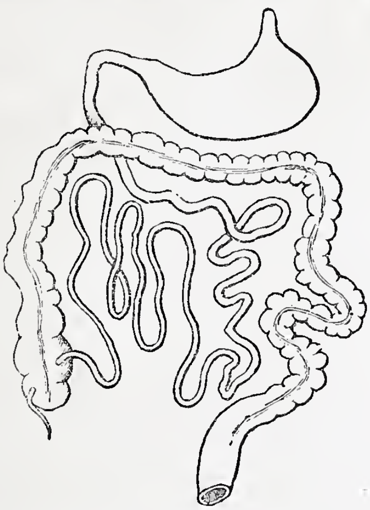
ANATOMY AND PHYSIOLOGY.

CHAPTER XIX.

THE INTESTINES.

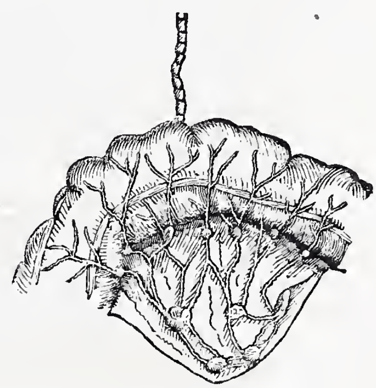
THE *intestines* form a membranous tube nearly six times the length of the body, about five-sixths of this length belonging to the small intestines, and about one-sixth to the large. The small intestines are the canals into which the chyme is received from the stomach; and when digestion is completed, the large serve chiefly as receptacles for the refuse which is to be expelled from the body.

In the figure, the small intestine is seen commencing from the smaller or right extremity of the stomach, and passing to the right side. It lies close below the liver, and turning downward, receives from it the gall-duct, and from the *pancreas,* the duct bringing its secretion, so that these fluids may mingle with the food; then going across the spine to the left, it twists and forms a great number of convolutions which lie chiefly in the middle of the belly, round about the navel, and finally terminate in the large intestine, in the right flank. In the drawing, the turns are not represented exactly as they are placed in the belly, but as separated and spread out in order to render them distinct. Neither is the small intestine represented by more than half its proper length; otherwise the numerous convolutions would have made the whole figure quite confused. The whole intestine is lined with a continuation of the velvety membrane which lines the stomach, and which is constantly moistened by a mucous secretion. The thickness of the gut is formed of muscular fibres, arranged in two layers, as seen at the left end of the figure, the outer layer being longitudinal, and the inner layer circular. When these fibres contract, their effect is to narrow the gut, as in the middle of the figure, and at the same time to draw the portion next farther down, upward to the contracted part, over the contained food, just as one draws up a stocking over the foot that is pushed into it. The effect of the gradual and generally uniform contraction of these fibres is to propel the food downward; and if the belly of an animal newly killed be opened, the bowels are seen moving in the manner of a bunch of earth-worms creeping through among one another,—whence the name of *vermicular* motion, which has been given to it. The gall-ducts enter the small intestine about six inches after it leaves the stomach; and the moment the bile mingles with the chyme, a chemical change takes place, and the separation of the nutritious parts from the refuse begins to go on. A creamy-looking white fluid appears on the surface of the food, next to the mucous membrane, and is sucked up by an infinity of small vessels called the *absorbents,* which will be described by and by. In performing all this process, the obvious use of the great length of the alimentary canal is, that every part of the food may be turned about, and be successively presented to the mouths of those vessels, so as to have its nourishing particles fully removed. The food therefore becomes gradually thicker and drier as it passes down, and is stained of a yellow colour from the admixture of bile; but it still remains perfectly sweet, and without any bad smell, until it gets into the large intestines, where it puts on the character of *fæces,* or useless matter.



The large intestine is seen to commence by a blind end, into the side of which the small intestine opens. A valve is here placed to prevent the regurgitation of the fæcal matter into the small bowels; and this it always does, except the force exerted to overcome it be very considerable. A figure of this very curious structure would have been shown here, but it is one of those parts of which no idea can be given by a drawing to a person unacquainted with them; they require to be seen and handled before they can be appreciated, and there are many such in the body. (A similar remark, by the by, was made in describing the valves of the heart.) A curious appendage, about the size of a large earthworm, is seen hanging from the blind end of the large gut, which in man is merely rudimentary. In purely graminivorous animals, the intestines are much longer than in man, and have several of those contrivances for delaying the less nourishing food upon which they subsist, until all its useful particles can be absorbed. In carnivorous animals, again, the intestinal canal is short, because their food is so highly nutritious, that its digestion is very quickly completed. Man occupies an intermediate place between these, and his bowels, like his teeth, indicate distinctly the mixture of the food which he is intended to derive from both the animal and vegetable kingdoms. From this blind pouch, then, the great gut ascends in the right flank, crosses over the belly below the stomach, descends in the left flank, forms a twist like the letter S, and then turns into the pelvis to open outwardly at the anus.

It has already been stated that the nourishing part of the food, the *chyle,* is absorbed from the intestines by an infinity of small vessels, having a close affinity to veins. Their structure is very like that of veins, being provided with valves, giving them a knotted appearance, which prevent the fluid they convey from taking a retrograde course. They are not more than the thirtieth of an inch in diameter, and are so transparent, that they are not visible when empty. If a dog be killed about two hours after a full meal, these vessels are seen in great numbers arising from the bowels, and filled with a white milky fluid, whence they receive the name of *lacteals,* (Latin, *lac,* milk). These vessels unite at the right side of the spine into a trunk about the size of a goose-quill, which at length pours its contents, containing all the nourishment of the body, (except the watery parts which seem to be taken up by the veins,) into the great vein of the upper part of the body, at the junction of the neck with the shoulder. It will be understood from this description, that since the new fluid is poured into a vein, not into an artery, it must necessarily be exposed to the air in the lungs, along with the current of the venous blood; this process probably completing its change into blood before it is circulated over the body.



There is another set of vessels of precisely the same kind, called *lymphatics,* which are very difficult to discover in dissection, because the fluid which they convey is not milky, but transparent lymph. These arise from every part of the

body, and have for their office the removing of the worn-out parts, which are no longer serviceable, and which are to be replaced by new deposits from the blood. The lymph is poured into the duct which has been spoken of in the preceding paragraph, and is mixed with the blood in the veins, so that afterwards it may be expelled from the body through the lungs, the liver, the kidneys, and the skin. The lymphatic and lacteal vessels are included under the common name of *absorbents*. They both pass through *glands*, which are roundish bodies (see last figure) about the size of hazel nuts, in which the absorbents subdivide and reunite, apparently for the purpose of mixing thoroughly the lymph and the chyle together.

The absorbent vessels and glands are very subject to disease in those individuals who are of a scrofulous temperament. The glands are very liable to enlarge, inflame, burst, and suppurate, particularly in the neck, armpits, and groins, and produce sores which are very tedious in healing. Sometimes in scrofulous children, the larger branches from the intestines become obstructed before they arrive at the main duct, so that all the food they eat, (and they generally have voracious appetites), never does them any good, because it never gets into the circulation. Such children are generally small and puny, with sharp thin faces, and large tumid bellies.

The whole of the contents of the belly are covered with a thin shining membrane, called the *peritoneum*, which also lines the boundary walls of that cavity. It is of the same nature as the membrane which lines the chest and covers the lungs, and as that which surrounds the heart. Its smooth polished surface is evidently intended to permit the constant gentle motions of the bowels to go on easily, without our being at all sensible of them. This surface is kept moist by a thin liquid, the evaporation of which is the reason why the body of an animal newly killed is seen to smoke when opened and exposed to the air. When this fluid is poured out in too great quantity, the bag of the peritoneum becomes distended with it, and constitutes the disease called dropsy. When medicines have no effect in reducing this, it becomes necessary to tap the patient; that is to say, to insert a small tube with a sharp point into the cavity of the belly, so as to permit the water to run out. This membrane is exceedingly liable to become inflamed, and when inflammation does come on, it runs a very rapid course, and generally proves speedily fatal. It is from this inflammation that many of those females sink, who perish after child-bearing.

Let us now devote a page to a notice of the diseases of the alimentary canal.

The stomach is rarely the seat of inflammation. It is so accustomed to have all things indiscriminately, and often recklessly, poured into it, that it would not be fit for its place in the body, if it were too easily put wrong. Many poisons, however, such as vitriol, arsenic, and corrosive sublimate, produce death by exciting in it violent inflammation. The stomach is nevertheless subject to a very low degree of inflammation, or rather irritation, which gives great uneasiness to its possessor. There are many, particularly among the female population, and these not in the lowest ranks, who can scarcely swallow any food, without its being succeeded by a feeling of distension and a sense of uneasiness, not amounting to actual pain, but as distressing as if it were, —producing headach, giddiness, coldness of the feet and of the surface generally, acidity, with eructations of gas, and sometimes the bringing up of a mouthful of fluid. These annoyances last till the three or four hours are passed, during which the food remains in the stomach. Ailments of this kind are exceedingly difficult to remove, for a plain reason, because the stomach cannot be allowed to rest; it must always go on with its work to a certain extent, and the only ease it can get is, that the aliments introduced shall be as easily digestible as possible. It is not easy to lay down any rule for this, although the account given in the preceding article of the digestibility of different substances will furnish some data; but the stomachs of those troubled with indigestion are most capricious, and we sometimes see them reject anything simple, and evince what we would consider the most extraordinary predilections. Mild laxatives, tonics, bitters, &c., all may take their turns as assistant remedies; but nothing can be persevered in long, and a constant reference to the medical attendant is necessary. Small blisters over the stomach, or crops of pustules brought out by rubbing the skin with tartar-emetic ointment, are often most beneficial.

Sometimes, after long disorder of the stomach, perforation takes place, and its contents escape into the cavity of the belly, producing violent inflammation and a hurried death. *Cancer* is a disease which attacks the stomach after the middle period of life is passed; it consists of a thickening of its coats, forming a growth which sometimes can be felt even from the outside, and generally ulcerated upon its internal surface. It produces the most distressing symptoms, burning heat, constant craving for food and drink, with inability to retain them, and at length the patient dies, worn down to a shadow.

Inflammation of the bowels takes place after exposure to cold, or the swallowing improper food. Pain marks its approach, and generally obstinate costiveness; and unless active treatment be had recourse to, the result is speedily fatal.

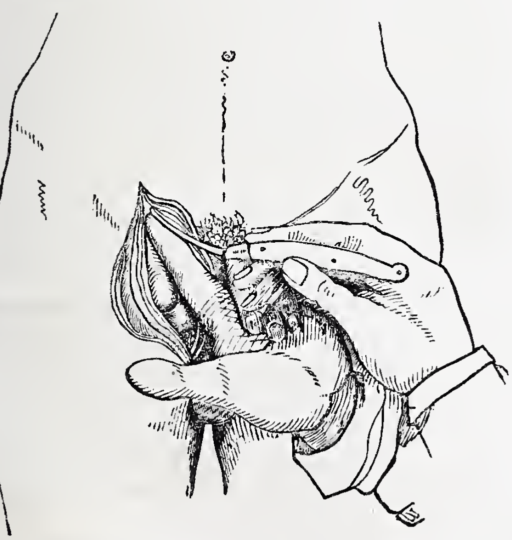
A quickened action of the bowels, hurrying through them whatever has been taken into the stomach, together with an increased quantity of the mucus which naturally moistens this lining membrane, constitutes a *diarrhœa* or looseness. This may be caused by any substance which disagrees with the stomach, especially by new vegetables when they first come in; or by a more remote cause, application of cold to the body when heated, which drives the blood in upon the internal organs. In this country, however, the lungs are the parts most apt to suffer from this last cause Sometimes the flow of bile is much increased at the same time; and one is said to have a *bilious diarrhœa*. Then again, the lining membrane may become inflamed and ulcerated, while the purging of bile continues, mingled with blood, and attended with severe griping pains; and the patient is said to have *dysentery*. This is a complaint of hot climates, but we have it also, especially in the heats of autumn. If, again, vomiting of bile be joined to this purging, the complaint is called *cholera*. A dreadful form of this, the epidemic cholera, passed over great part of the globe a few years ago, committing great devastation in its path. It was in this country in 1832 and 1848, and the sad sufferings and deaths of their relatives and neighbours must be fresh in the memories of many of our readers.

A very painful affection of the bowels, but without danger, is *colic;* consisting of a distension of the great gut with an unusual quantity of gas, which is prevented from escaping by a spasmodic contraction of some part between it and the natural outlet. Some hot drink generally gives speedy relief. A curious form of colic is common among painters, the *lead colic*, depending on the absorption of white lead into their systems, and is accompanied by a loss of power in the muscles of the fingers and wrist.

It is a curious thing that other animals sometimes take up their abode within ours, especially in the bowels. Besides some rarer forms, there are three species of intestinal worms with which we are familiar. Hundreds of very small white ones take up their abode in children, infesting the lowest part of the gut, just within the anus, and giving great annoyance from the irritation which they cause, besides occasioning a falling away in health and strength. Worms, from five to eight inches long, are found in the small intestines in some individuals, and even make their way up into the stomach, so as to be thrown up by the mouth. A rare kind is the tape-worm, about half an inch broad, and from ten to twenty feet long; it is generally solitary: indeed, one such companion will be quite sufficient. The presence of intestinal worms is always accompanied by loss of health; strong medicines are required to drive them out, and careful attention to the state of the bowels afterwards, to discourage a second invasion

It were a neglect did we not notice the sluggishness of the bowels, so apt to be induced in an artificial state of society, such as exists in towns. A movement of the bowels should take place every day; but from want of time, or want of convenience, this is neglected; the daily call is not attended to, and by and by it ceases to be made. A necessity is now felt for medicine, and this is repeated day after day, and week after week, until the health is seriously and permanently injured. There are plenty of pills prescribed by the regular, and advertised by the irregular practitioner, many of which are good and useful; but care should be taken to have proper ones recommended at first, and not to persevere too long in the use of the same ones, as the bowels become habituated to the repetition of the same stimulus, and require a new one. The use of the enema syringe, by which warm water is thrown into the gut, so as to procure an evacuation, has become very common of late years, and is very good; for it secures the stomach and small intestines from the irritation of constantly repeated doses of medicine. The instrument, with directions for use, may be had at a very moderate rate from all the surgical instrument-makers.

A not uncommon complaint connected with the belly, particularly among the labouring population, is *rupture*. This consists in a portion of the bowels being forced out from its natural position, through some weak point in the walls of the belly, forming a swelling, covered by the skin. This swelling requires to be pressed up into the belly, and means must be used to keep it from coming down again. The apparatus used is generally a truss, consisting of a steel spring covered with leather, which goes round the waist, having a pad on one end, for making pressure on the weak part. Sometimes the rupture becomes strangulated; that is to say, it swells so that it cannot be replaced, and then it would mortify; so that death would be the inevitable consequence, were not an operation had recourse to, by which the stricture or edge of the opening is divided, so that the protruded parts are got returned. This is one of the most delicate operations in surgery, and fortunately, when it is had recourse to in time, it is one of the most successful. The wood-cut represents the surgeon introducing a narrow blunt-pointed knife to divide the stricture, after having brought the bowel into view, by a careful incision through the superjacent parts.



In speaking of the morbid state of the stomach and bowels, we should not omit to mention the curious, but simple means, by which poisons are now easily withdrawn from the stomach. A gum-elastic tube, about the thickness of one's little finger, is passed down the throat into the stomach, and a brass pump which holds about half-a-pint, is attached to the end of it. Two or three pints of warm water are now thrown into the stomach, to dilute the matters there, and the whole contents are then easily withdrawn. The syringe can act either as a sucking or forcing pump, so that, with fresh supplies of water, the stomach may be thoroughly washed out.

MATHEMATICS.

PRINCIPLES OF ALGEBRA.

Chapter II.—Multiplication.

9. Our first notions of multiplication are derived from operations on whole numbers; from these we are led to regard it as a short mode of repeating a quantity as many times as there are units in the multiplier. We have already found it necessary to extend this fundamental signification of the term, so as to include within it those cases in which the multiplier is a fraction, (Arithmetic, chap. vi. art. 7. vol. i. p. 231); and as the literal symbols used in algebra are necessarily general, denoting fractional quantities as well as whole numbers, we must understand our terms in the same enlarged sense. Thus, the direction to multiply a by b, does not necessarily imply the repetition of a, a certain number of times, for b, the multiplier, may be less than 1; it is simply a direction to form with the quantity represented by a, another quantity which shall have the same relation to a, that b has to 1. If b be formed by repetitions of 1; that is, supposing it to denote a whole number, then the product of a by b will be formed by repeating a as many times as 1 is repeated to form the number b; and if b be formed of a certain number of equal parts of 1; that is, supposing it to be a proper fraction, then will the product of a by b be formed by taking the same parts of a. The word *times*, which we employ in multiplication, must thus be understood to signify either repetition or partition, of the multiplicand, according as the multiplier is greater or less than 1.

10. In arithmetic we have had frequent occasion to make use of the sign $\times$, to indicate that the quantities between which it was placed were to be multiplied together. In algebra we occasionally employ it for the same purpose: thus, $a \times b$ signifies, in an arithmetical sense, that the quantity a is to be multiplied by the number b; and in an algebraic sense we call $a \times b$, the product of a by b. The same is also sometimes expressed by a point: thus, $a \cdot b$ is the same as $a \times b$. But, the multiplication of literal quantities is more simply expressed by writing the letters in succession in the form of a word: thus, ab has the same meaning as $a \times b$ and $a \cdot b$, and is more concise, and therefore usually adopted.

11. The quantity ab is therefore, in algebraic language called the product of the factors a, b; and to multiply this product ab by another number c, we write abc, and this we call the product of the factors a, b, c. From this then we perceive that multiplication in algebra, like addition and subtraction, is merely an indication of the arithmetical operation which is to be performed upon the numbers represented by the literal quantities. Thus, supposing $a = 4$, $b = 5$, $c = 6$, then

$$ab = 4 \times 5 \text{ or } 20, \text{ and } abc = 4 \times 5 \times 6 \text{ or } 120.$$

From this, therefore, we may conclude generally, that the rule for the multiplication of simple algebraic quantities is the following:

Write the letters consecutively in the order which is most convenient, without the interposition of any sign; and use the sign $\times$ between numerals. The alphabetical arrangement of the letters is usually preferred.

Thus, $a \times b \times c \times d$ is written $abcd$, and, reciprocally, every expresion, such as $a\ b\ c\ d$, formed of several letters written immediately in succession to one another, designates always the product of the numbers represented by these letters.

We made tacit use of this convention in Article ii., (p. 127,) when illustrating the manner of writing numerical coefficients, which, being factors of the literal quantities to which they are prefixed, are obviously comprised in this rule. Thus, $6abc$, indicates that the quantity abc is taken 6 times, and is, therefore, according to our definition, the product of the four factors, 6, a, b, c; or of the two factors, 6 and abc.

12. To indicate a multiplication in which there are several simple products having coefficients, we might apply the rule given above without error.

Thus, $4\,ab \times 3\,cd \times 5\,mq$ might be written $4\,ab\,3\,cd\,5\,mq$.

But as multiplications may be made in any order without affecting the numerical result of the operation,* we profit by this circumstance to collect, for the sake of simplicity and symmetry of expression, all the numerical coefficients together by the arithmetical rule. Thus, instead of writing

$4\,ab\,3\,cd\,5\,mq$, we write $4{\cdot}3{\cdot}5\,abcdmq$, or $60\,abcdmq$,

which is more concise, and in every respect more convenient. It is, however, to be borne in mind, that this is only a conventional conveniency; and that the one form of expression is identical with the other in signification.

13. From this, then, we conclude, that if the quantities† to be multiplied have coefficients, these must be multiplied together as in common arithmetic, and that the literal product must be written consecutively, as directed in the rule, Art. 11. The following are examples:—

$$2\,ax \times 4\,bb \times 5\,ax = 2 \times 4 \times 5\,ax\,bb\,ax = 40\,aa\,bb\,xx$$
$$\tfrac{1}{2}\,px \times 2\,pq \times 7\,ax = \tfrac{1}{2} \times 2 \times 7\,px\,pq\,ax = 7\,a\,pp\,q\,xx$$
$$\tfrac{1}{3}\,pq \times 3\,p \times 3\,q = 3\,pp\,qq \qquad \tfrac{1}{7}\,xy \times \tfrac{3}{4}\,yz \times \tfrac{1}{2}\,xz = \tfrac{1}{28}\,xx\,yy\,zz$$
$$\tfrac{7}{8}\,an \times \tfrac{5}{7}\,mq \times \tfrac{3}{4}\,pr \times am = \tfrac{15}{32}\,aa\,mm\,n\,p\,q\,r.$$

14. The multiplication of complex quantities is resolvable into the same operation as that explained, as exemplified in arithmetic; when the quantities to be multiplied together consist of several parts, every part of the one must be multiplied by every part of the other, and the sum of all the partial products must be taken as the total product of the two quantities. In algebra, these partial products can be found by the rules given above; although, as we shall presently see, the process presents a peculiarity which is not found in the arithmetical operation.

Let it in the first place be required to multiply $a + b$ by c, that is, to find c times $a + b$.

Here the product of a by c is ac, and the product of b by c is bc; but the product of the sum of a and b by c, is manifestly the sum of the product ac and bc; that is $ac + bc$.

Hence‡ c times $(a + b) = c\,(a + b) = ac + bc$.

Again, let it be required to multiply $a - b$ by c; that is, to find c times $a - b$. The partial products as before are ac and bc; but since a is greater than $a - b$ by the quantity b, it is therefore clear that c times a; that is, ac, is greater than c times $a - b$, by the quantity bc; consequently, bc must be subtracted from ac, which gives $ac - bc$ for the product required.

Hence c times $(a - b) = c\,(a - b) = ac - bc$.

The same reasoning clearly applies whatever be the number of terms in the multiplicand. These two cases, therefore, furnish the following rule for the multiplication of a complex quantity, by a quantity of one term; namely, *Write the multiplier into every term of the multiplicand.* In the practical application of this rule, we commonly multiply from left to right. The following is an example:—

$$\begin{array}{ll} \text{Multiply} & ab + c - 2\,d + 3\,m - 4\,n - qx \\ \text{by} & 2\,z \\ \hline \text{Product} & 2\,abz + 2cz - 4\,dz + 6\,mz - 8\,nz - 2\,qxz. \end{array}$$

The following exemplify alse the use of brackets in this rule:—

$$2\,ax\,(a + b - c + 1) = 2\,aax + 2\,abx - 2\,acx + 2\,ax$$
$$\tfrac{1}{2}\,xy\,(x - z) + z\,(1 - z) = \tfrac{1}{2}\,xxy - \tfrac{1}{2}\,xy + z - zz$$

$$ab\,(x - 1) - bc\,(1 - x) - cd\,(1 + x) =$$
$$abx - ab - bc + bcx - cd - cdx$$
$$m\,\left\{\,n\,(a + b - c - d + 1) + pp\,\right\} =$$
$$amn + bmn - cmn - dmn + mn + mpp.$$

15. When the multiplier is composed of several terms, we have the following cases:—

I. Let it be required to multiply $a + b$ by $c + d$. Here $a + b$ is to be taken $c + d$ times, that is c times $+\,d$ times; now c times $a + b$, is $ac + bc$, and d times $a + b$, is $ad + bd$; but $c + d$ times $a + b$ must manifestly be the sum of these partial products; that is, $(ac + bc) + (ad + bd)$ which, taking away the brackets, becomes $ac + bc + ad + bd$.

2d. Let it be required to multiply $a - b$ by $c + d$. Here c times $a - b$ by c is $ac - bc$, and d times $a - b$, is $ad - bd$; and the sum of these products is $(ab - bc) + (ad - bd)$; that is, taking away the brackets, $ab - bc + ad - bd$.

From these and similar examples then, we conclude that *the multiplier being the sum of several terms, the total product sought is composed of the sum of the partial products of the multiplicand by every term of the multiplier.*

Suppose now that the multiplier contains a subtractive term, it is clear that the products formed by that term, must be taken with a contrary sign to that which they have by the preceding rule. Treating this condition as above, let us inquire,

II. What is the product of $a + b$ by $c - d$? This question is by definition the following: what is c times $(a + b) - d$ times $(a + b)$? Now c times $a + b$ is $ac + bc$, and d times $a + b$, is $ad + bd$; consequently,

$$c \text{ times } (a + b) - d \text{ times } (a + b) = (ac + bc) - (ad + bd)$$
$$\text{that is } (c - d) \text{ times } (a + b) = (ac + bc) - (ad + bd)$$
$$\text{or } \ (a + b) \times (c - d) = ac + bc - ad - bd,$$

and this last is therefore the product sought, with the brackets struck out.

2d. What is $a - b$ multiplied by $c - d$? The answer to this question must obviously depend upon the same reasoning as that employed in finding the answer to that preceding. We have in the first place—

$$c \text{ times } (a - b) - d \text{ times } (a - b) = (ac - bc) - (ad - bd)$$
$$\text{that is, } (a - b) \times (c - d = ac - bc - ad + bd$$

by taking away the brackets of the product.

From these two, and other like examples, we conclude, that *when a term of a multiplier is preceded by the sign —, every partial product formed by that term will have the contrary sign to that of the corresponding term of the multiplicand.*

16. The preceding operations and the rules to which they lead, are directly deducible from the principles exemplified in Art. 14.

Thus putting $c + d = m$; then $(a + b) \times (c + d)$ becomes $(a + b)\,m = am + bm$; and putting for m its value we have

$$am + bm = a\,(c + d) + b\,(c + d) = ac + ad + bc + bd$$

Again putting $c - d = n$: then $(a - b) \times (c - d)$ becomes $(a - b)\,n = an - bn$; and putting for n its value we have

$$an - bn = a\,(c - d) - b\,(c - d) = ac - ad - bc + bd.$$

17. The multiplication of all complex quantities may be reduced to this last case by representing the sum of the positive terms in each of the two factors by a and c respectively, and that of the negative terms similarly by b and d; it then only remains to assign the values of the partial products ac, bc, ad, bd.

To render this plain, suppose that it is required to multiply $5\,x - 3\,y + 2\,z$ by $xy - 2\,z$. The multiplicand may obviously be written $(5\,x + 2\,z) - 3\,y$: let $5\,x + 2\,z = a$ and $3\,y = b$ then $5\,x - 3\,y + 2\,z = a - b$; similarly put $xy = c$ and $2\,z = d$; then $xy - 2\,z = c - d$. The product of $a - b$ by $c - d$ is

$$ac - ad - bc + bd$$

but $ac = (5\,x + 2\,z) \times xy = 5\,xx\,y + 2\,xy\,z$

$ad = (5\,x + 2\,z) \times 2\,z = 10\,xz + 4\,zz$

$bc = 3\,y \times xy = 3\,xyy$ and $bd = 3\,y \times 2\,z = 6\,yz$

$\therefore ac - ad - bc + bd = 5\,xxy + 2\,xyz - (10\,xz + 4\,zz) - 3\,xyy + 6\,yz$

$= 5\,xxy + 2\,xyz - 10\,xz - 4zz - 3\,xyy + 6\,yz$

which is the product of $5\,x - 3\,y + 2\,z$ by $xy - 2\,z$.

18. Observing the results obtained in these cases, we find that

* It must be observed that this proposition is here assumed, not proved; and we may remark, that although so simple as almost to be thought self-evident, no faultless demonstration of it has yet been given. The following is an instance, $ab = ba$ for $a \times 1 = 1 \times a$; that is, a taken 1 time is the same as 1 taken a times; but $a \times b$, is b times as great as $a \times 1$, and $b \times a$ is also b times as great as $1 \times a$, which is the same as $a \times 1$; therefore $ab = ba$. This proof may be extended to

$$abc = cba = cab = bca = bac.$$

† By quantities we understand such magnitudes as can be represented by numbers; we may therefore without impropriety speak of their multiplication and division, bearing in mind, however, that a multiplier is always an abstract (never a concrete) number: the multiplier is the answer to the question, How many times?

‡ A quantity written before or after a quantity placed within brackets, is to be multiplied into every term of the enclosed quantity.

every term of the multiplicand is multiplied by every term of the multiplier, and that where the terms so multiplied have both the same sign, that is both $+$ or both $-$, their product has the sign $+$, and where they have different signs, that is $+$ and $-$, or $-$ and $+$, their products take the sign $-$. We may therefore conclude that they establish the following general rule for the multiplication of complex algebraic quantities together. *Multiply every term of the multiplicand by every term of the multiplier (according to the rule for simple quantities), and put $+$ before the products of terms which have the* SAME *sign, and $-$ before the products of terms which have* DIFFERENT *signs.* The first terms which have usually no sign prefixed, must be considered to have $+$.

The following example, while it illustrates this rule, shows also the common mode of arranging the operation to facilitate reduction when the partial products contain like terms.

$$\begin{array}{lllllll}
\text{Multiply} & 2\,a + b\,c - 2\,bb & & & & & \\
\text{By} & 2\,a + b\,c - 2\,bb & & & & & \\
\hline
\text{P. from } +2a & 4\,aa & +2\,abc & -4\,abb & & & \\
\quad . \;\; . \; +bc & . & 2\,abc & . & . & +bbcc & -2\,bbbc \\
\quad . \;\; . \; -2bb & . & . & -4\,abb & . & . & -2\,bbbc + 4\,bbbb \\
\hline
\text{Total product} & 4\,aa & +4\,abc & -8\,abb & & +bbcc & -4\,bbbc + 4\,bbbb
\end{array}$$

In writing down the partial products, it will be observed that we have arranged all the like terms under each other; this enables us to perform the reductions with more readiness. These reductions being effected in taking the sum of the partial products, the result is the product sought.

19. When we wish simply to indicate the multiplication of two complex expressions, we enclose each of the factors between brackets, and write these in succession without the interposition of any sign. For instance the expression

$$(a - b)\,(c - d) \text{ is the same as } (a - b) \times (c - d)$$

and indicates the product of $a - b$ by $c - d$ as before shown. Some of the old authors put the factors under lines as below.

$$\overline{a - b} \times \overline{c - d} \text{ and } \overline{a - b)}\;\overline{c - d.)}$$

but this notation is neither so neat nor so exact as the other, and ought therefore to be abandoned. We shall often have occasion to make employ of the brackets to denote the multiplication of quantities, and therefore shall give a few instances of their use in the following examples which the student is expected to verify :—

Multiplicand,	Multiplier.	Product.
$ax + bx + c$	$a - b$	$aax - bbx + ac - bc$
$aa + 2\,a\,b + bb$	$a - \frac{1}{2}\,b$	$aaa + \frac{3}{2}\,aab - \frac{1}{2}\,bbb$
$xx - \frac{1}{2}\,x + \frac{2}{3}$	$\frac{1}{3}\,x + 2$	$\frac{1}{3}xxx + \frac{11}{6}\,xx - \frac{7}{9}\,x + \frac{4}{3}$

Multiply $1 - x + xx - xxx$ by $1 + x$. Ans. $1 - xxxx$

$$(xx + 2\,xy + yy)\,(xx - 2\,x + yy) = xxxx - 2\,xxyy + yyyy$$
$$(xx - \tfrac{3}{4}\,x + 1)\,(xx - \tfrac{1}{2}\,x) = xxxx - \tfrac{5}{4}\,xxx + \tfrac{11}{8}\,xx - \tfrac{1}{2}\,x$$

20. *Definition.* When the same quantity is multiplied into itself any number of times, the result is called a *power* of that quantity.

Thus x multiplied by x, or xx is called the second power of x
xx . . . . x, or xxx . . the third . of x
xxx . . . . x, or $xxxx$. the fourth . of x

and so on; and x when compared with xx, xxx, &c., is called the first power of x. The second and third powers are called the *square* and *cube*, from certain relations between them and the geometrical square and cube of a line of x units.

21. The following three questions connected with this subject, lead to results which are of frequent use, and therefore ought to be remembered.

I. What is xx when $x = a + b$? This question is equivalent to the following: What is the square or second power of $a + b$? For, on the assumption $x = a + b$ we have

$$\begin{aligned} xx = (a + b)\,(a + b) &= aa + 2\,ab + bb \\ &= aa + bb + 2\,ab \end{aligned}$$

that is, *The square or second power of a quantity composed of two parts, a and b, is composed of the sum of the squares of the these parts* INCREASED *by twice their product.*

To render this clear, let the number 27 be resolved into two parts 20 and 7; then the squares of the parts are 400 and 49, and double their product is 280, then according to the theorem,

$$\text{The square of } 27 = 400 + 49 + 280 = 729.$$

II. Let x in xx be $a - b$; then we have

$$\begin{aligned} xx = (a - b)\,(a - b) &= aa - 2\,ab + bb \\ &= aa + bb - 2\,ab \end{aligned}$$

that is, *The square or second power of the difference of two quantities, a and b, is the sum of their squares* DIMINISHED *by twice their product.*

Let the two numbers be 100 and 5; their squares are 10000 and 25, and twice their product is 1000; therefore

$$\text{The square of } 100 - 5 \text{ or } 95 = 10000 + 25 - 1000 = 9025$$

III. What is xy when $x = a + b$ and $y = a - b$?

$$\text{Answer } xy = (a + b)\,(a - b) = aa - bb$$

from which we perceive that *if the* SUM *of two numbers be multiplied by their* DIFFERENCE, *the product is the difference of the squares of the numbers.*

Let us take for a numerical example the sum 17 of the numbers 10 and 7; multiplying this by the difference $10 - 7$ or 3, we have the product 17×3 or 51, which is equal to the difference between 100, or the square of 10, and 49, or the square of 7.

The following are applications of these formulæ: *

$$\begin{aligned}
\text{Square of } 4\,ax + 2\,vy &= 16\,aaxx + 16\,avxy + 4\,vvyy \\
. \;\; . \;\; . \;\; 2\,a\,(x - y) &= 4\,aa\,(xx - 2\,xy + yy) \\
&= 4\,aaxx - 8\,aaxy + 4\,aayy \\
. \;\; . \;\; (a + b) + c &= (a + b)\,(a + b) + 2\,c\,(a + b) + cc \\
&= aa + bb + cc + 2ab + 2bc + 2ac \\
. \;\; . \;\; . \;\; (a + b) - c &= aa + bb + cc - 2ab - 2ac + 2\,bc
\end{aligned}$$

$$(\tfrac{1}{3}\,ax + \tfrac{1}{2}\,ay)\,(\tfrac{1}{3}\,ax - \tfrac{1}{2}\,ay) = \tfrac{1}{9}\,aaxx - \tfrac{1}{4}\,aayy$$

What is $ax - bx$ when $x = a - b$? *Ans.* square of $a - b$

What does $(a + x)\,(a - x)$ become when x is changed into $x + h$?

Ans. $aa - (x + h)\,(x + h) = aa - xx - 2\,xh - hh$.

Show that

$$(a - b)\,(a + b) - (b - a)\,(b + a) = 2\,(a + b)\,(a - b)$$

The student should accustom himself to write such developments as the preceding at *sight*; they are of very frequent occurrence, and a little practice is all that is necessary to enable him to accomplish the process mentally. The following theorems will afford him some further practice.

If a and b be two numbers of which a is the greater, and if S be the square of their sum, D the square of their difference, and P the product of their sum and difference, show that

$$\begin{array}{ll}
S + D = 2\,(aa + bb) & S - D = 4\,ab \\
S + P = 2\,(aa + ab) & S - P = 2\,(ab + bb) \\
D + P = 2\,(aa - ab) & P - D = 2\,(ab - bb) \\
\multicolumn{2}{c}{S + D + P = 3\,aa + bb}
\end{array}$$

The student would do well to verify these results by the substitution of particular numbers for a and b.

* *Formula* is the name which we give to an algebraic expression, showing the arithmetical operations to be performed in finding a particular result which is often required. It shows the arithmetical relation which the *data* (that is, the quantities involved in the question) ought to bear to each other in accordance with the conditions given. In the plural sense, we may either write the English form, *formulas*, or the Latin form, *formulæ*. *Data* is the plural word; the singular is *datum*, which is used by surveyors in speaking of the *datum* line to which their calculations respecting heights and inclines are referred.

ACCOUNT OF THE IRON MINES OF CARADOGH, NEAR TABREEZ IN PERSIA,

AND OF THE METHOD THERE PRACTISED FOR PRODUCING MALLEABLE IRON DIRECTLY FROM THE ORE.

By James Robertson,

Civil and Mining Engineer, Major Persian Service, and late Director of the Shah's Ordnance Works, Persia; Cor. M.W.S., and Cor. F.A.S.S.

We have no historical record from which to ascertain the period at which the iron mines in the district of Caradogh were first wrought. But there is every reason to suppose that they were resorted to from the remotest antiquity. The district itself is very secluded, and is of a wild, forbidding aspect; it has, without almost any interval, formed part of the Median, and latterly of the Persian empire; and, under the rule of native princes, has all along been free from the revolutions which have so frequently convulsed Western Asia. The iron mines themselves also bear evident marks of antiquity. They form large quarry-like excavations, thickly surrounded by immense tumuli of iron-sand and small pieces of ore, thrown out in the course of working. Upon a rough calculation, founded on the size of the excavated hollow which it exhibits, one only of the numerous iron mines which abound in the district was estimated by the writer to have now afforded above 4,000,000 cubic feet of iron-ore. Taking the specific gravity of the ore at 5, a cubic foot would weigh about 300 lb., and consequently seven cubic feet would weigh about a ton; and 4,000,000 cubic feet, the total quantity excavated from that mine, would weigh 571,428 tons. Now, at the present day, 2000 horse loads is a full allowance for the yearly quantity carried away, and as each horse carries about 2 cwt., we have a total of 200 tons per annum as the exported produce at present. It may be reasonably assumed, that this quantity has, upon an average, never been exceeded during the many ages in which the mines have been wrought. Indeed, this estimate certainly exceeds the actual average yearly produce; for although a considerable quantity of Russian iron is now imported, to supply the increasing wants of the inhabitants, it cannot be imagined that, in periods of their early history, the natives would require nearly so much iron as they now do. Upon that assumption, and without taking into account the other neighbouring mines, it would follow that 2857 years have passed since the soil was first removed from the surface of the mine alluded to. Were the other neighbouring mines taken into account, the antiquity of the whole would be proportionally increased. The writer has not by any means stated these as calculations, or as at all approximating to accuracy, but still he thinks that, from such data, fanciful as they may in some measure appear, an estimate may legitimately be formed of the very great antiquity of the Persian mines.

The native smiths are dispersed in small hamlets, situated in the woods which clothe the sides of the ravines, through which the mountain torrents flow into the river Arras (the ancient Araxes). The iron which is produced, although soft, is extremely tough. It is much superior to the Russian iron, with which the greater part of Asia is now supplied, and is manufactured chiefly into horse-shoes, and horse-shoe nails, for which there is a great demand in Tabreez and the surrounding districts, and among the Koords or nomadic tribes who frequent the mountain pastures in summer. The trade in it is shared between the Mahomedans and the native Armenians; and although by no means extensive or deserving the name of the "Persian iron trade," it gives employment to a considerable part of the population, in quarrying the ore, burning the charcoal, and transporting these articles to the forge.

There are numerous mines in Caradogh, affording iron ore of the most valuable description, and of various kinds; but those held in the highest estimation are the Jewant, Koordkandy, and Marzooly ores.

The Jewant mine is situated in an immense vein of red iron ore. This ore, on its fracture, often exhibits streaks of prismatic colours, as if at one time it had been subjected to the action of heat; quantities of iron-sand are dispersed in the interstices of the vein.

The Koordkandy mine, situated on the summit of a very steep mountain, produces rich magnetic iron-ore, from a vein of great dimensions. The Marzooly mine also affords excellent magnetic iron-ore in great abundance. The vein in which the last is situated runs across several hills, and is in most parts 100 feet in width.

In working these mines, the richest pieces only of the ore are carried away, the remainder is thrown aside. They are worked very irregularly, and without concert, as there is no restriction imposed as to the mode of mining by the government. A few individuals sink a shaft through the rubbish, and excavate as much as they require; another party soon after arrive, and fill the first hollow up in the course of sinking another shaft; and in this way the rubbish is repeatedly turned over, and gradually subsides and is consolidated into a mass as the ore is removed from beneath, thus forming a serious obstacle to any one who might attempt to work the vein in a more regular manner. The ore is carried to the villages only during the summer, as the depth of the snow in winter renders the mountain paths impassable. It is there retailed to the smiths, who purchase a horse-load of 2 cwt. for about 1*s.* sterling, or 10*s.* per ton.

The ores above described, when smelted singly, produce that kind of iron which by English workmen is called *hot-short*, and by the Persians *salt-iron.* The smiths, however, by means of a mixture, produce iron of an excellent quality, which they term *sweet-iron.* The most common mixture is two parts Jewant ore to one of Koordkandy, and two parts of Koordkandy to one of Marzooly.

Materials for smelting the ore are found in an extensive natural forest which occupies the central parts of the district of Caradogh. This forest covers the flat bottoms between the mountains, and spreads to a considerable height up their sheltered sides, dwindling into dwarf trees and bushes in the elevated and more exposed situations. It consists chiefly of coppice oak, which springs from the roots of trees cut and recut during a long succession of years. This jungle is partitioned among the villages situated on its confines, the inhabitants of which earn a livelihood by supplying the city of Tabreez and adjoining towns with fuel.

The charcoal is made in the following manner: a rectangular hollow is dug in the earth, about twelve feet long, six feet wide, and four feet deep. The sides are formed of the natural ground, or common alluvial cover; a small sloping door-way is cut at one end, and at the other a chimney is built, rising to the height of about six feet. The pit is filled up to the level of the ground with cut branches of all dimensions, placed horizontally and lengthways in the hollow, and are covered over with earth, and secured effectually against the admission of air, excepting by a small hole in the built-up door-way, which is left open to produce a current; the heap is kindled through the small opening in the door-way, and after it has burned for two or three days the covering is removed, and the charcoal thus produced is then stored for sale. One of these hearths will produce about one ton of charcoal, which sells at 13*s.* sterling.

The charcoal thus produced, however, is seldom used in the manufacture of iron, the smiths preferring that prepared in the following manner: The cut branches are merely laid horizontally on the surface of the ground, and piled up to a considerable height; having been lighted from beneath, they are allowed to burn in the manner of an open fire, till the smoke and flame have nearly ceased; the fire is then quenched with water, when there remains a charcoal which is very light, and is found to reduce the ores of iron in a much less time than the heavier charcoal produced by the first method.

As the iron is manufactured on a very small scale, a very simple forge answers the purpose. It consists merely of a hollow hearth dug out of the clay floor of the hut, about fourteen inches square in the bottom, and nine inches deep, for receiving the ore and fuel; and of another hearth immediately thereto adjoining, intended to receive the slag, and consisting of a larger excavation, about three inches deeper than the former, and situated betwixt it and the wall at the other extremity in which the chimney is constructed. A wall is built on each of the two sides, two or three feet high, and the whole is covered over with large stones capable of resisting the action of the fire. The whole of the first or iron-hearth into which the blast is introduced is left

open above, and at the sides; but a low wall is built next the bellows to prevent the heat from injuring them. The whole is afterwards plastered over with clay and chopped straw, in order to maintain the draught of the chimney entire. The chimney is carried up through the walls of the hut, and seldom rises higher than its roof.

The construction and dimensions of these hearths will be best explained by the accompanying drawings.

The operator having carefully selected charcoal of a small size and light weight, proceeds to clear it from dust and sand with a small meshed riddle, removing all the heavy pieces of charcoal or stones that may be accidentally mixed with it. The raw ore being next selected and mixed, and being broken into small pieces about the size of a hazel nut, is thoroughly moistened with water. A dam is then made between the iron and slag hearths, composed of charcoal and charcoal-dust well rammed down, and the top is coped

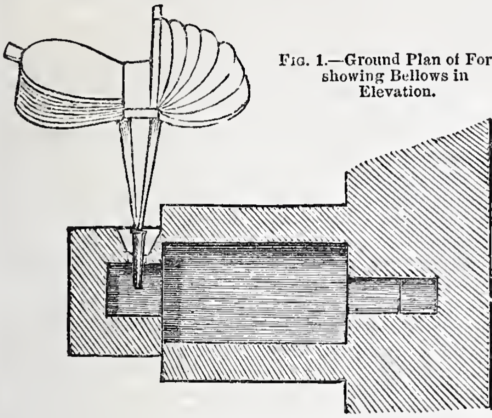


Fig. 1.—Ground Plan of Forge, showing Bellows in Elevation.

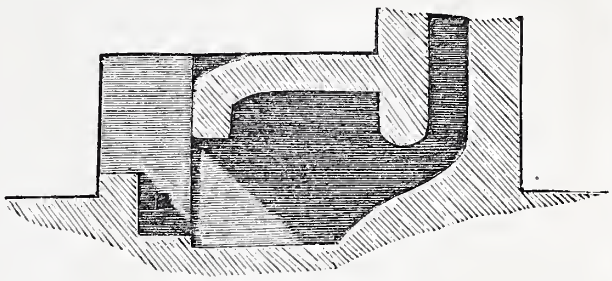


Fig. 2.—Vertical Section of the Forge and Chimney.

Fig. 3.—Side View of Forge.

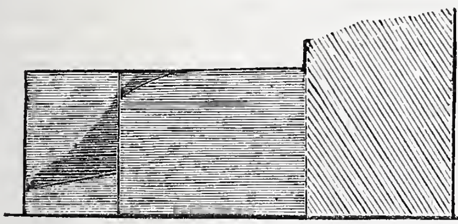


Fig. 4.—Side View of Forge.

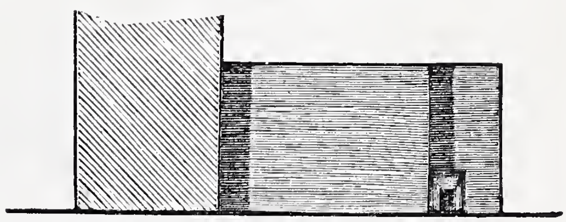


Fig. 6.—Side View of Bellows.

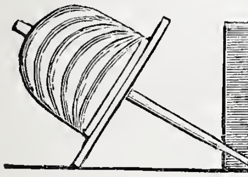


Fig. 5.—End View of Forge.

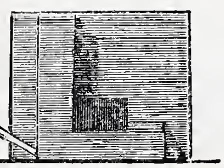
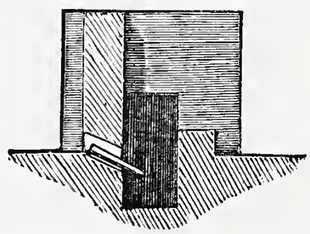


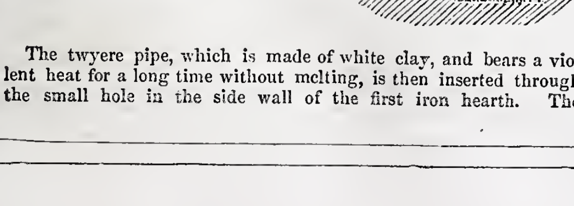
Fig. 7.—Section of Ore-Hearth through the Centre.



Scale of Feet.

0 1 2 3 4 5 6 7 8 9 10

with iron-slag from a former smelting. The following sketch shows this arrangement:—



The twyere pipe, which is made of white clay, and bears a violent heat for a long time without melting, is then inserted through the small hole in the side wall of the first iron hearth. The point of the pipe is made to reach half-way across the iron hearth, and within six inches of the bottom, as shown in fig. 7. A layer of charcoal, of three inches thick, is then spread over the bottom of the iron hearth, and upon this two other layers laid across, one directly under the twyere pipe of about six inches in breadth and three inches deep, and the other at the front of the hearth of the same thickness, to correspond with the overlying part of the dam. The two trenches which are thus formed are filled up with the moistened ore, well rammed down. A second layer of charcoal, in a state of ignition, is thereafter laid over the former under the twyere pipe, and other successive layers of charcoal and ore are filled in, corresponding with those in the bottom. When the hearth has been nearly filled up in this way, a covering of charcoal is spread over the surface of the whole on a level with the top of the dam. The bellows are then blown, and a workman, who stands at the side of the hearth, keeps constantly pushing down the charcoal in the middle with an iron rod, and from time to time throws small quantities into the centre of the fire as it gradually subsides. At the commencement, one man at a time is sufficient to blow the bellows

but, towards the close, two are required, the one standing behind the other. The bellows, of the form shown in the figures 1 and 6, are in general use all over Persia. After blowing for an hour or an hour and a half, part of the twyére pipe having melted from the violence of the heat, the blast is stopped for a moment, for the purpose of pushing the twyére pipe farther in towards the centre of the hearth. It is then again continued, and in about three hours, or three and a half hours from the commencement, the ore becomes consolidated, but not fused. The blast is then again stopped until that half of the bloom which is next to the slag hearth is turned over with an iron bar, and pushed on the top of the dam, while the other half is turned round to the centre of the fire. The blast is then immediately recommenced, and the metal of the half bloom in the centre of the fire speedily falls to the bottom. The remaining half of the bloom is then drawn into the centre, and treated in a similar manner, very little charcoal being placed on the top of the fire during this part of the process. When the metal has entirely disappeared by sinking to the bottom of the hearth, the whole semi-fluid mass is stirred about for a quarter of an hour longer with an iron rod. The blast being then stopped, the twyére pipe is withdrawn, and the operator taking his shovel pushes the burning charcoal together with the dam into the lower hearth ; the slag immediately runs off, and exposes the glowing iron lying in the bottom of the upper hearth ; the metal is then beaten with the back of the shovel into a more solid state, and after being dexterously cut with an iron chisel bar from the sides of the hearth, and forced from the bottom, it is removed to the floor of the hut with a large pair of tongs. The iron is next beaten with large hammers as it lies on the ground, in order to expel the slag and other impurities from its pores ; and after being in this way formed into a rough mass, it is lifted to the anvil, when it is again hammered into a more regular shape. It is next cut into two pieces with large wedge-shaped hammers, and is then fit for being drawn into bars of the dimensions required.

At a single smelting, one hearth generally affords about 30 lb. of malleable iron, to produce which there is only required about double that quantity of ore, and three times the weight of charcoal. One smith with his assistants will make about three or four smeltings in one day, or 1 cwt.

It must strike every one acquainted with the iron manufacture, that this *yield* is in a high proportion to the materials used. In England, about four tons of raw ore and eight tons of coal are required to produce one ton of bar-iron ; while, by the process above described, the same quantity of iron, of a much superior quality, is produced in Persia from less than half of these materials. The greater productiveness is no doubt to be attributed in a great measure to the superior richness of the Persian ores, and the use of charcoal ; but the simplicity of the process must also have a considerable share in diminishing the waste of materials ; for the roasting, smelting, refining, puddling, shingling, balling, and drawing-out, or something very similar is all there effected, as it may be said, at one heat, and in a very few hours.

The rich iron-ores of Cumberland and Lancashire, and many others in Britain, particularly the blackband ironstone of Scotland, which has of late years attracted so much the attention of iron-masters, if manufactured in the same manner, would undoubtedly produce similar results, and thus create a great saving in time, labour, and capital, as well as diminish the waste of materials.

Since writing the preceding, the writer has had an opportunity of becoming acquainted with a similar process to the one already described, now successfully practised near the town of Malatia on the Syrian frontier, in the central parts of Asia Minor. The iron-ores in this district are of the richest description, and were examined by the writer at the command of the Turkish government, with the view of establishing iron-works on the scale of British iron-works, for the supply of the Turkish ordnance. The method there pursued is, if possible, still more simple than that of the Persians, as the furnaces are in the form of a small cupola, and the fuel is simply dry wood.

ACCOUNT OF CLEGG'S DIFFERENTIAL DRY GAS-LIGHT METER.

By Professor Vignoles, C.E.

To those familiar with gas operations in general, there is no occasion to enlarge on the advantages of a good dry meter. It has been a desideratum ever since the use of a meter at all was first duly appreciated, and has often attracted the attention of many scientific and practical men, who have attempted to realize this desirable object.

This will, doubtless, be deemed quite a sufficient justification for so experienced an engineer as Mr Clegg, to present himself before the public as the inventor of an instrument which he considers likely to realize what appears to be so much required.

The construction and action of this meter are based upon the established facts, that the heat and light from the various kinds of carburetted hydrogen gas are strictly proportionate to each other ; and, by the application of that fact, in combination with an apparatus, acting on the same principle as the differential thermometer of Leslie.

By this apparatus may be measured most delicately the smallest differences of heat ; and consequently the consumption of gas may be registered in proportion to its illuminating power.

Let two hollow glass cylinders, each about one inch in diameter, and three inches long, be connected together in the centre of their lengths, by a hollow bent tube of the same material, being such as will be afterwards described when treating of the mechanical arrangements for a six-light meter, and delineated in the accompanying figures. Let these cylinders and the connecting tube be perfectly exhausted of air, and let as much alcohol be introduced as will nearly fill one cylinder, leaving a vacuum in the other—or at least leaving it without air, and with only such vapour therein as may arise from the alcohol. Now as pure alcohol boils, *in vacuo*, at 56° of Fahrenheit's thermometer, the smallest excess of heat, above this temperature, applied to the cylinder having the alcohol therein, will cause the liquid to evaporate, and, by its consequent elasticity, will drive the spirit below the vapour into the colder cylinder ; and the velocity with which the alcohol will be driven out from one cylinder to the other will be in exact proportion to the quantity of heat applied, twice or three times the cause producing twice or three times the effect, and so on. For, let air or gas be heated to a uniform temperature—say to 150° of Fahrenheit—and, when so heated, let it be directed to impinge upon one of two glass cylinders, such as those above described, with any given velocity. If this velocity be doubled, then double the quantity, or volume, or body, of heat will be passed, and consequently double the effect—that is, double the velocity with which the alcohol is driven—must be produced, such being an unerring and natural law. Although twice the effect be thus produced, the temperature of the air or gas has not been increased ; it is only the flow or quantity which has been augmented ; and this must be what is to be understood by quantity of heat. The best criterion of the soundness of the above statement is, that these facts have been determined from, and are founded upon, repeated and concurring experiments—the only true source of philosophical induction.

Such, then, being established, it became a leading principle ; and the next step was to ascertain, by further experiments, how to apply this scientific fact to the art of measuring the quantity of heat applied to one of the above-described glass cylinders, and of registering the same ; for, this being accomplished, there was at once obtained an apparatus, whereby may be determined the exact flow of air or gas in a given time ; in other words, a gas-light meter, such as the present instrument. The first consideration therefore was, how to heat a given quantity of gas to a certain uniform temperature ; for, the gas being thus heated, and allowed to flow out at a given velocity, a uniform flow of heat was obtained.

Now, for the purposes of measuring this flow of heat, in the instance of a gas-meter, the source of heat is present by the inflammable gas itself ; and, after numerous experiments, it was fully and conclusively ascertained, that a jet of gas issuing out of an orifice, perforated in the side of a small solid brass cylinder—such as will be afterwards described, and shown in the annexed figures—will heat the said cylinder to a uniform given temperature, whatever be the height of the said jet ; for, with a

small flame, the jet clings, as it were, and is in immediate contact with the solid cylinder; whereas, when the flame issues from the orifice with considerable velocity, still the longer jet only imparts the same degree of heat to the solid cylinder as did the smaller one; the increased or lengthened flame being, in this latter case, driven away from any closer contact by its own velocity, or rather by the velocity due to the pressure of the gas issuing from the orifice. This fact having been thoroughly established by repeated experiments and practice, the necessary apparatus of the gas-meter, for the practical application of the fact, became very simple.

The next point expedient to be determined accurately was, the proper superficies of a receptacle, to be heated by or from such a solid cylinder as the one just described; which surface would be sufficient to communicate the requisite heat to such portion of the whole quantity of gas to be measured, as it was necessary to pass through the receptacle, without altering the temperature thereof in any perceptible degree. This point was ascertained, as the preceding ones were, by repeated experiments; and, further, it was found advisable that the receptacle for heating the gas should be well clothed with the best non-conducting substance, to keep it at a proper temperature. The proportionate surface of the receptacle having been determined, certain other proportions and dimensions were established, which, as applicable to a six-light meter, are given in the figures accompanying the subsequent mechanical description.

Lastly, it remained to be found what quantity of gas, heated in the manner previously described, and discharged upon one of two such glass cylinders as before mentioned, would be sufficient to expel the alcohol therefrom, and drive it into the other cylinder. Numerous experiments and long practice have determined this quantity to be no more than about one-seventh part of the whole gas requisite to supply the number of burners, the consumption whereof is to be measured.

This, being conclusively established, led to the consequent arrangement of dividing the flow of gas as applied from the main, so as to pass them separately through two openings, one of which should have its area six times that of the other, whereby six-sevenths of the gas admitted from the main might flow towards the burners, without passing through the working part of the meter, leaving the remaining, or one seventh part, to perform the necessary functions of registering the amount of the whole quantity. The simple manner in which this arrangement is carried into effect is duly pointed out by the figures, and is described in the subsequent explanation of the whole of the mechanical contrivances for the proper working of the meter.

Two openings, exposed to the stream of the same volume of air or gas, however they may differ in their respective areas, will always admit quantities thereof strictly proportionate to those areas. Thus, through a circular aperture of one inch in diameter, will pass precisely sixty-four times as much air or gas as through a circular aperture of only one-eighth of an inch in diameter; and this will hold unerringly, and under all pressures, allowing only for the additional friction the gas is exposed to in passing through the smaller opening, compared to its friction through the larger one. This theory is so well authenticated by practice, that it can require no further illustration here. It is only the smaller quantity, therefore, or one-seventh part of the gas which is necessary actually to pass through the working and registering parts of the meter; and from this portion being very dry and at a high temperature, an immense advantage is derived; for, as the decomposing action on the materials of the meter ceases when the gas is hot and dry, there will be little or none of that wear and tear, going on so rapidly in the ordinary water meter, from the ammonia, sulphur, and galvanic action, which are the principal agents of deterioration, and which also act—though not to the same extent—upon other dry meters, only exposed to the usual aqueous vapour which gas absorbs at the ordinary temperature of the atmosphere. In hot dry gas the galvanic action ceases; the ammonia, which exists in the form of a gas, will, when not exposed to aqueous vapour, pass off harmless; but where there is moisture present, the ammoniacal gas is instantly absorbed, and becomes a strong alkaline solution, acting on the wrought-iron parts of the meter.

From Sir H. Davy's early experiments it appears, that—taking weight—100 grains of water absorb thirty-four grains of ammoniacal gas; consequently—taking bulk—one cubic inch of water takes up 475 cubic inches of that gas. [See Henry's Chemistry, vol. i. p. 397, third edition.] The sulphur in the gas combining with hydrogen forms sulphuretted hydrogen gas. Water absorbs twice its own bulk of this gas—[see the same work]—and when so impregnated, the gas is very destructive to brass and copper; but, when dry, it is harmless.

It will be observed that, in the dry meter now describing, all those parts which are exposed to six-sevenths of the whole quantity of gas admitted, consist either of cast iron, pure tin, or German silver, none of which materials are acted on injuriously by gas in the usual state of the atmosphere; and as there is no water, and the remaining—only one-seventh—part of the gas working through the meter at a high temperature, the action of decomposition on the materials is altogether avoided.

All these requisites having been most conclusively determined *à priori*, it may be proceeded to consider the arrangements necessary to put the above philosophical facts to practical application, in the construction of the "New Differential Dry Gas-light Meter."

First, the two glass cylinders, as previously described, are to be suspended in such a manner, that the alcohol may be expelled from the one cylinder placed in the lowest position, and driven to occupy the other cylinder placed in a higher position. This being effected, the upper cylinder will descend and act as a pendulum, imparting motion with a power equal to the weight and height of the fluid raised. To ensure, however, the proper pendulous motion, it is necessary to attach a counterbalance to the weight of the glass cylinders and their connecting tube; and this is further required, for the purpose of regulating the quantity of alcohol to be driven into the upper cylinder. The descent of this cylinder constitutes one vibration, the counter weight giving it such sufficient preponderance or momentum in its descent, as to cause it to impart motion, with certainty, to a train of wheel-work revolving in the way usual in gas-meters; and the vibration, and consequently the corresponding consumption of gas, or light, thereby becomes registered. The manner of suspending the glass cylinders, and fixing the counterbalance weight, is hereafter described.

The next considerations are—1st, How is the tube or receptacle before mentioned—and which will be called the "heater"—to be placed over the lower cylinder, so that, in discharging thereupon the hot gas, it may not communicate any of its heat to the upper one? and 2nd, How to place the upper cylinder in a medium always at the same temperature as that of the room in which the meter is to work? it being absolutely necessary to keep the two cylinders at two greatly opposite temperatures, that shall always bear the same relative degree or difference to each other.

The first of these objects is arrived at easily by placing a tin plate between the two cylinders, as is clearly shown in the figures, and pointed out in the mechanical description following. The second necessary effect is attained by enclosing the whole meter in a thick cast-iron case; in the interior of which, and forming parts of the same casting, two semi-cylindrical projections, or hoods, are so placed as nearly to surround that glass cylinder which alternately becomes the uppermost one. The conducting power of this mass of iron is amply sufficient to carry off all the heat radiating from the case of the heater—this heater being, as before stated, enveloped in a case or clothing of the best non-conducting material—and not only so to radiate this heat, but to be always of the same temperature as the room in which the meter is placed. These hoods, therefore, constitute a very essential part of the apparatus; for, if the temperature of the upper glass cylinder were to vary materially, so would that of the lower one, and consequently the rate of the meter would also vary; but, by this very simple contrivance, the temperature of the heater, and that of the lower glass cylinder, will be always of the same relative temperature to that of the upper cylinder.

Take an example:—Let the "heater" be at 150° of Fahrenheit, and the room—and therefore the cast-iron parts of the meter—at 60°, then the gas which flows from the heater on to the lower glass cylinder will be at the same temperature, viz., at 150°, and thus the moving power, originating from the meter jet, will be equal to 90° which represents the heat imparted by the meter jet, such being a constant and uniform quantity. If the temperature of the apartment, and consequently that of the iron case, hoods, &c., be raised to 80°, the temperature of the heater will be increased 20°, becoming 170°, the moving power being constantly 90°. It has been deemed necessary to dwell particu-

larly on this part of the arrangement, which is absolutely essential to the correct registration of the meter, and which has been contrived in so complete and effective a manner, and by means which cannot possibly be deranged.

The preceding are the leading features of this philosophical arrangement for measuring the flow of gas of a given quality. With the same heat the same results will obtain; the only variation that can take place must be by change of temperature of the small jet of flame which issues from the hemispherical end of the solid brass cylinder, this being the governing principle; consequently, with an increased temperature of the solid brass knob, caused by a brighter flame (and which imparts its heat to the tube or receptacle for the gas, called the heater), or *vice versâ* (the same quantity of heated gas being discharged on the lower glass cylinder), the flow of alcohol from the one cylinder to the other, and consequently the vibrations will be quicker or slower in exact proportion to the difference of temperature. Hereby is obtained a measure of light; in fact, a photometer; that is, a light-meter; in other words, a gas-light meter, rather than gas-meter, which is the more accurate definition, since the article to be measured is light, not gas; for it is well known that the illuminating power of coal gas varies 30 per cent., according to the process used in its production, and the quality of the coal from which the gas is obtained.

The principle of this meter being based on the fact, that the intensity of the heat from a gas flame is as the brightness or illuminating power, it may be well, for the information of those who have not made this branch of chemistry their study, to give the following short extracts from the most approved authorities :—

From Dr Henry's Experiments on Coal Gas, published in the Manchester Philosophical Transactions :—

"By the first train of experiments, I endeavoured to derive, from a careful analysis of the compound combustible gases, a measure of their illuminating power, admitting of more exact appreciation than the optical method of a comparison of shadows. The one which I was led to propose as the most accurate, and, I still think, entitled to preference, was the determination of the quantities of oxygen gas consumed, and of carbonic acid formed by the combustion of equal measures of the different inflammable gases, that gas having the greatest illuminating power which in a given volume consumes the largest quantity of oxygen. The average results of a great variety of experiments were comprised in the following table :—

Kinds of gas.	Oxygen gas required to saturate 100 measures.	Carbonic acid produced.
Pure hydrogen	50	—
Gas from moist charcoal	60	35
Ditto from wood (oak)	54	33
Ditto from dried peat	68	43
Ditto from cannel coal	170	100
Ditto from lamp oil	190	124
Ditto from wax	220	137
Olefiant	284	179."

From the preceding, it is clearly proved that the illuminating power of gas depends upon the quantity of oxygen consumed, and of carbonic acid produced during combustion.

The object of Dr Henry's paper was only to prove the illuminating power of the gas; in order therefore to prove that the heat from the combustion of any gas increases in the direct ratio of the oxygen consumed, the following is extracted from Professor Graham's Treatise on Chemistry :—

"From the late researches of Despretz and of Bull, a very interesting rule has been obtained; it is as follows :—'That in all cases of combustion the quantity of heat evolved is proportional to the quantity of oxygen which enters into combination.'"

And in Henry's Chemistry, ninth edition, p. 422, we find it stated, that "by the combustion of denser gases, a higher temperature is produced." See also Williams on Combustion.

The heat and light from the gas having been thus demonstrated to be proportionate to each other, we have, in the preceding apparatus, a meter which will measure the quantity of light given forth, which is the real end to be desired, and the following description of the mechanical arrangements may be now proceeded with.

Fig. 1.—Front elevation, with the case of the meter removed.

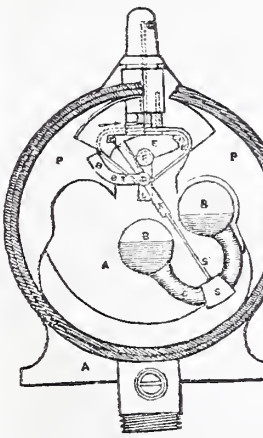


Fig. 2.—Section from the front to the back of the meter.

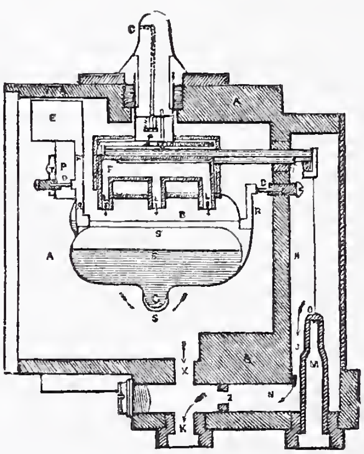
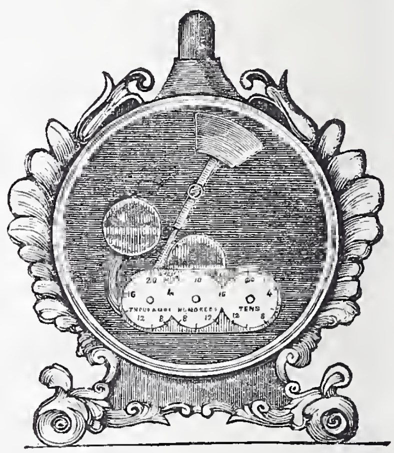


Fig. 3.—Front view of the meter in an ornamental case.



Figs. 1, 2, 3, represent different parts and positions of "Clegg's Patent Differential Dry Gas-light Meter." They are drawn to a scale of 3-10ths of an inch to one inch, or in that proportion to a full-sized meter, capable of measuring the consumption by six large gas-light burners, that is a "six-light meter." The same letters refer to the same parts in all the figures.

A A A, is a cylindrical cast-iron vessel, being the case of the meter of about a quarter of an inch thickness of metal made thicker at particular parts requiring it, and five inches outside diameter. P P are hoods or projections, parts of the same casting of the entire case or vessel, the important functions of which have been previously explained. The references to the working parts, distinguished by the other letters, will be made in the subsequent explanations.

For the sake of distinctness and simplicity of description, it may be best to show, first, the manner in which the gas flows through the vessel, and the action of all those parts which are essential to the mere meter, taking up afterwards certain auxiliary mechanical contrivances, quite independent of the general principles on which the meter is constructed, or of the actual operation of registering the light, these contrivances being chiefly introduced for preventing frauds.

When the gas is first turned on at the main stop-cock, it flows into the meter through the openings or pipes, M, to a valve at O, which opens into a vertical passage at the back of the meter. Along the upper part, H, of this passage flows a small portion only, (viz. one-seventh of the whole), gas finding its way into a receptacle called the "heater," into which it enters through the pipe at I, and thence fills every part of the main body of the meter, where the working parts are disposed; the direction of this flow or current of gas is indicated by short light arrows along its entire course. The remaining larger portion, viz., six-sevenths, of the gas flows down the lower part, J, of the above vertical

passage at the back, and along the horizontal tube, N, at the bottom of the meter, and through the regular disc or opening, Z, fixed therein, and thence passes direct towards the burners, through the main exit K. The area of this disc, Z, is exactly six times that of the opening, I, into the heater and working parts of the apparatus. This larger portion of the gas flows through these lower passages of the meter without influencing any of the working parts, and for that reason is called the "neutral gas," and the direction of its flow or current is marked by long dark arrows. The smaller portion of the whole supply may be called the "working gas." A minute quantity of this gas flows from the body of the meter through two small openings, perforated in a solid brass cylinder, G, entering at the bottom, where this cylinder is screwed on to the top part of the heater F, and issuing out in the front of the cylinder near its top, in a jet at *c;* this is called the "meter jet," and forms an important part of the arrangement; it may, indeed, be designated as the originator of the moving power; in fact, the prime mover of the meter. The orifice, whence issues the meter jet at *c*, is plugged with platina to prevent corrosion, or any other wear and tear. This meter jet, immediately after opening the main stop-cock, should be lighted, that it may at once impart a corresponding amount of caloric to the heater, and thereby raise the "working gas," flowing through that receptacle, to the same temperature. This receptacle, with the connecting pipes and the brass cylinder, may be considered as forming one apparatus, under the general designation of the "heater;" *m, m,* is a pasteboard covering for the heater, and all the parts connected therewith, except the solid brass cylinder, pasteboard being selected as the slowest conducting substance wherewith to surround them.

The working gas, raised to a high temperature, flows down from the heater through the vertical pipes L L L, and impinges on the top surface of the lowest one of two hollow glass cylinders B B. These cylinders are connected together in the centre of their lengths by the bent hollow glass tube C, the whole being exhausted of air, and partially filled with alcohol, as described in the commencement of this paper. A tin collar, S, is attached to the bent tube C, and to a large tin plate S′, passing between the two glass cylinders; this plate unites to brass arms or bars, R, R, on each side, and by these the whole glass instrument vibrates on pivots, or points of suspension, at the extremities, D D, of two screws, one passed through the side of the cast iron case of the meter, and the other sustained from the bent iron bracket or arm, T, attached to one of the hoods P. E is the weight, or bob, fixed to the upper end of the two brass bars, R, to act as a counterbalance in the vacuum, and for the purposes previously described, the pendulous motion thus obtained acting on the train of wheelwork of the registering dials. The use of the tin plate S′, passing between the two glass cylinders, is to prevent any of the heated gas flowing down upon the lower cylinder from affecting the upper one, and thereby altering the proportionate difference of temperature between the two cylinders, which forms the basis of the principle on which the vibrations are kept up. The "working gas," after acting on the lower cylinder, as above described, flows down through the main body of the meter, and along the outlet at the bottom, where it re-unites with the "neutral gas" coming through the regulating disc Z, and with it passes to the general exit K, towards the burners.

This, then, is the description of the whole of the mere meter, and it will be evident that no alteration in the measure can, at any time, take place by the leakage of valves, there not being any in the working parts, neither is there therein any membrane or partition, that when such become acted upon, and rendered porous by the action of the gas, any portion can escape through them unmeasured; the moving power being the small light at the top (the "meter jet"), it will likewise be apparent that there is not the least resistance to the flows of the gas, and that thus the gas passes through every part of the meter in the same uninterrupted way it would flow through a pipe, neither interfering with the perfect steadiness of the lights, nor requiring any pressure.

The remaining mechanical contrivances are for stopping-off the gas from the burners when the meter jet is not lighted, for giving a temporary extra temperature to the heater, for a few minutes only, when the meter jet is first lighted, and for the regulation of that jet—when the meter is originally fixed in its place—according to the pressure; the whole contrivances being chiefly, as before observed, for preventing fraud, and ensuring proper registration.

To prevent the gas flowing to the burners, except when the meter jet is lighted, and the meter registering accordingly, a valve which communicates with the supply of gas is opened or shut by the expansion or contraction of a pyrometer, the heat to which is communicated by the small jet at G.

ON WALLS APPROPRIATE FOR FRESCO-PAINTING.

By Charles H. Wilson, Esq., A.R.S.A.—Report to the Commissioners of the Fine Arts.*

Mural paintings were executed upon plaster of various kinds, laid upon walls variously constructed; several examples also occur of frescos which were painted upon plaster laid on lathing. The comparative durability of works executed under these circumstances will be explained by examples; but, in the first place, without reference to the injuries sustained from external causes.

It is not possible to commence with a description of the earliest Christian edifices in Italy; these monuments, in the Byzantine style, do not offer any examples of painting of a date coeval with their erection; they were first decorated internally with mosaics; and the few remains of paintings, properly so called, in such buildings, have been so frequently repaired that they cannot be referred to as examples of ancient art. With regard to paintings, the date of which is assignable, and which have not been so repaired, the first to be considered are those executed on ashlar walls; these are sufficiently numerous to afford satisfactory evidence. The oldest examples are to be found in Italian Gothic structures, such as the church of Assisi, and the cathedrals of Orvieto and Siena: in the first of these churches there are numerous specimens of the earliest application of the revived art of painting upon walls; in the others instances also occur, which, although less important, may be adduced in illustration of the subject. A few general observations will be offered on the construction of these edifices, and of those subsequently erected as the Gothic style fell into disuse.

The interiors of the above-mentioned buildings are finished in fine masonry; the walls, externally and internally, have ashlar facings, and are hearted with rubble; and although Gothic architecture never attained to a high degree of excellence in Italy, the constructive principles of the Gothic architects are apparent there as in other countries, but not developed in equal perfection; and as there is, in the ornamental detail of edifices of the period, a constant struggle between the introduced Gothic taste and the tradition of the classic, the same struggle is in the constructive principles. In some examples the walls are of marble, in others of stone, in others again of brick; but in every case the mere workmanship is very fine.

When, at a subsequent period, the ashlar walls of these buildings were covered with paintings, one, or at most, two, very thin coats of plaster were laid on, sometimes formed of lime and sand, at other times of lime and marble dust; and the pictures were painted upon these grounds. They were in most cases commenced when the plaster was wet; but as, from its thinness, such plaster would dry very rapidly, the pictures were finished in distemper, and therefore cannot be called frescos: and it may be inferred that this mixed art was a consequence of painting upon such thin coats of plaster, made so of necessity, as thicker coats would have destroyed the proportions of the building which were already completed in the stone or brick work: this is exemplified in the door of the Lady Chapel in the cathe-

* C. H. Wilson, Esq., Director of the Government School of Design at Somerset House, was, some time ago, employed by Her Majesty's Commissioners on the Fine Arts, to proceed to the Continent to collect information relating to the objects of the commission. Having been furnished with the necessary instructions, he left England in autumn and returned early in spring. During the period of his absence, he visited the principal buildings on the Continent, in which fresco and other mural pictures of any note are preserved, for the purpose of ascertaining the mode in which they had been executed by the middle-age artists; and also the kind of ground and wall best adapted for the execution of works of that nature, and for their preservation. After his return, Mr. Wilson embodied the results of his observations, and such other useful information as he had obtained, in a Report to the Commissioners on the Fine Arts, of which the following is that part relating to the construction of walls on which frescos have been executed. In a future page we intend to give the succeeding part of the Report, which relates to the mechanical operations of fresco-painting—the mode of executing the picture.

dral of Orvieto, the thin shafts and mouldings of which are covered with a coat of plaster (to receive the painting), kept as thin as possible to avoid destroying the proportions of these details.

The above are specimens of paintings on ashlar walls. A church of a still earlier date, namely, that of S. Miniato at Florence, affords an example of brick walls on which at a subsequent period pictures were painted: other examples of paintings on brick will be cited.

With the progress of the revival of classic taste may, I think, be remarked a declension in constructive skill, or at least the introduction of a very careless practice; the rubble and external ashlar facing being retained, while the internal facing is done away with, and plaster is substituted. We also find internal walls so built as frequently not to be at right angles with each other, sometimes not quite perpendicular, and in all cases very uneven on the surface; for these rubble walls are generally built of mixed and indifferent materials, the fragments, apparently, of former buildings, such as small stones, broken bricks, and even bits of tile.

Many fine works of art are painted upon walls built in this careless manner, and thus the unfortunate inequality of their surfaces, which has been so often remarked, and accounted for in so many ways, is readily explained; at times the inequality is increased indeed by the actual bulging of the intonaco; this again is the result of bad workmanship, as in most cases no pains were taken to give the intonaco a key to the mortar beneath: there are one or two curious instances of marking the under coat to give the finishing coat a proper hold, but the practice was not general.* These ill-built walls are frequently faced externally with marble, stone, or brick building of unexceptionable execution: it is therefore the more remarkable that no pains were taken to bring the internal wall to an even surface by means of plastering,† as could very easily have been done, and in fact as was subsequently done in some cases on equally bad walls, by the Caracci and their pupils.‡

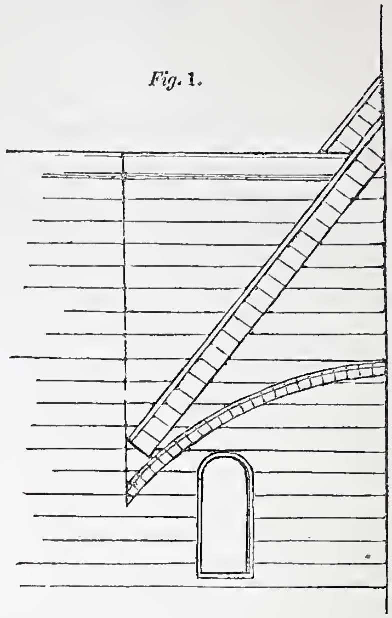
Pictures then are found on three kinds of wall: on the ashlar walls of Gothic edifices, on the brick walls of buildings of different dates, and upon coarsely built rubble walls of different kinds. To these are to be added frescos on lath, of which there are many examples in different parts of Italy.

Examples of paintings on ashlar walls.—The most important examples are those in the triple church of St Francis at Assisi. The walls of the lower church are in all probability finished entirely in ashlar stone-work; all the parts that can be seen, that is, those parts not covered with paintings, are so; in those which are painted the pictures seem to be in tolerable preservation.

The upper church is painted everywhere. The walls are internally finished in ashlar; the stones are very small, and being of a red colour, they look from the pavement like bricks set on edge; the seams are not very close, thus affording an excellent key for the plaster, which for the most part is firm; it has however fallen away in great masses near the top of the church, but this is to be attributed to the infiltration of water from the roof; in the transepts, portions have fallen away lower down, possibly from the effects of damp also; and as regards the construction, there seems from this instance to be no cause to doubt the durability of work of this kind.

In the Chapel of the Sacrament at Orvieto the wall is of fine closely-jointed ashlar, the stones being of considerable size; the wall moreover is perfectly dry. The first thin plaster-ground has been scored in a peculiar manner while it was moist: the plasterer has taken the point of his trowel and made numerous circular marks so as to give a key to the intonaco, but as the first coat was applied to the smooth wall, the plaster has fallen down and but little remains. This example seems also to offer another lesson: the walls act as buttresses, resisting the thrust of the great transept arches, and their peculiar construction is exhibited in the sketch, fig. 1. One of the walls is more weakened by windows than the other, and the plaster has entirely fallen off in the direction of the thrust.

Fig. 1.



Orvieto.

The plaster has also fallen off the fine stone-work of the doorway leading into the opposite chapel: and it is to be observed that the frescos of Luca Signorelli have a very uneven surface. The walls of the chapel present, externally, the same appearance as those of the chapel opposite, but they are a foot thicker, and an alteration has evidently been made in the window. It is not improbable that these walls were lined with a wall of tufo (on which frescos were frequently painted), the artist having perhaps thought it unsafe to paint on the ashlar wall.

There are some frescos in a small chapel in the Cathedral of Siena, painted upon plaster laid upon the marble wall; in this case the plaster has not fallen away, but there can be no doubt that in general the plaster is easily detached from ashlar walls. It may stand perfectly if not injured by damp or accident, but when injured it falls away in large masses, which is not the case with plastering on any other kind of wall. The frescos last mentioned in the cathedral of Siena are very wet in warm weather, from the condensation of the damp in the atmosphere in the cold wall. This of itself is a great objection to the execution of frescos on such walls.

Brick Walls.—The pictures by Spinello Aretino in S. Miniato at Florence have already been alluded to as specimens of an early date and in perfect preservation. The wall is evidently dry, and being well built, the surface of the paintings is even, and thus they are not injured by dust settling upon them.

The pictures by Giotto in the Chapel of the Scrovegni at Padua are upon brick; these also have an even surface, and although the colours have faded (possibly from the action of the light, as some of those on the same side with the windows are much stronger in point of colour than those opposite), it may be said that these pictures are generally in good preservation. Those on the vault have suffered from damp.

The library of the cathedral of Siena, painted in fresco by Pinturicchio (in 1502-3), is probably lined with brick. The walls of the cathedral are, it is true, of polished marble inside and out, but this library was added in 1450 by Pius II., and is in the revival style entirely. The frescos are perfectly even on the surface, which never is the case with paintings of the period on rubble walls, and although it would be so were the plaster laid on ashlar, yet as the damp never condenses on their surface, as in the neighbouring chapel already quoted, these frescos may be adduced as instances of the durability of this kind of painting upon brick walls. But we must look to vaulted ceilings chiefly

* Neither the Germans nor the Italians score or mark the plaster to give the upper coat or intonaco a hold, but they use a precaution in Germany which is more effectual, by mixing rough gravel with the first coats; the intonaco has thus a sufficient hold. The Genoese adopt the same practice.

† The words plastering and plaster are used in the general sense; it is not to be understood that plaster or gypsum is mixed with the lime.

‡ It is by no means intended to be asserted that this would be good practice, since the plaster, when of unequal thickness, is apt to crack.

for specimens of fresco upon brick, as the great majority are so executed, and on these in most instances the frescos are found in good preservation.

Pictures in the same situations in churches are, it is true, exposed to greater danger, there being nothing between the vault and roof, which is too frequently neglected; but in the Palazzi, where they have been properly taken care of, they are found to last perfectly well. The most remarkable in point of preservation are those by Beccafumi in the Palazzo Publico at Siena, which seem to be as brilliant as on the day when they were painted.

The Cappella Sistina appears to be a brick building externally, but Signor Bosio ("Architetto Camerale") having been employed to examine the roof, thought from what he then observed, that the walls were built of tufo faced externally with brick; they are from eight to ten feet thick; whether there is any internal facing of brick for the frescos it is impossible to ascertain, but it is not improbable that the Last Judgment is painted on a brick lining, as its surface is much more even than that of the other paintings in the chapel. Those on the vault must certainly be upon brick, and are well preserved.

The frescos in the Farnesina, which are on brick, are in excellent order; and the fact that Carlo Maratta repainted the blue backgrounds is no proof that such a step was required. The presumption of this artist is painfully proved by the unnecessary retouching with which he has injured the frescos in the Stanze of the Vatican.

The frescos of the later Florentine masters, in the cloisters of several of the convents in Florence, are on brick walls; and except where they have been wantonly injured, are in excellent order.

Of a later date there are the numerous frescos of the Caracci and of their scholars. In their time constructive care was exhibited; the workmanship is in every case excellent, the surfaces are smooth and even, and all their frescos are in good preservation, unless injured by accident. Those in the Farnese palace, St Andrea della Valle, S. Carlo de' Catenari, Sta. Maria Maggiore, and the Ludovisi and Rospigliosi Casini in Rome,—in numerous churches and palaces in Bologna and its neighbourhood,—in Modena, Piacenza, Parma, and elsewhere, may be instanced as proving the durability of fresco: all are on brick, and in all the plastering is excellent.

To this list, which refers to a considerable number of works, must be added the ceiling frescos in Genoa, nearly all on brick vaults, and nearly all in perfect preservation. These paintings are chiefly by Pierino del Vaga and his followers, by Cambiaso, Carlone, &c.

*Rubble Walls.**—Unfortunately some of the most precious works of the great masters are upon walls of this description, and to this their dilapidated state is to be in a great measure attributed. There are instances of such extensive ruin that the cause of the unevenness of the fresco is evident, and it is probable that the same effect invariably proceeds from the same cause. It is quite out of the question to suppose that the wall behind frescos with solid but uneven surfaces, can be ashlar; nor are they likely to be brick, as examples which are certainly painted upon plaster laid upon brick are quite even on the surface, and the external facings of brick in the walls where these uneven frescos are found, are perfectly even. Nor does the unevenness in every case proceed from the bulging of the intonaco (which is easily detected by tapping with the finger), for frescos are often very uneven on the surface yet quite solid.

In the Chapel of St Cecilia, in Bologna, the frescos by Francia and Costa are unhappily so much injured that the wall can be seen in several places. It is evidently of the coarsest rubble construction, and the frescos are very uneven on the surface. The walls of Sta. Maria Novella, at Florence, are of rubble stone, and the frescos in the choir present the same uneven appearance, as do those of Fra Filippo Lippi in the adjoining chapel.

The frescos by Avanzi in S. Giorgio, and by Titian and other artists in the Capitolo di S. Antonio at Padua,—by Masaccio in the Carmine, by Ghirlandaio in Sta. Maria Novella, and by Andrea del Sarto in the SS. Annunziata at Florence,—by Pordenone in S. Rocco at Venice, and in Sta. Maria in Campagna at Piacenza, have all very uneven surfaces, and all have consequently suffered from the accumulation of dust upon the inequalities, and from the cracking and breaking off of the plaster, partly owing to the bad masonry and partly to the careless way in which the mortar has been applied.

The inequality of surface observable in the frescos by Raphael and his pupils has often been remarked. I believe that this inequality is also entirely to be attributed to the manner in which the walls have been built, that is, of rubble alternating with courses of brick in the manner described by Palladio, under the head of "Muri di Cimenti." Signor Bosio says, "Since the building of what may be called Modern Rome, the greatest carelessness has prevailed as to the material, execution, and finish of the masonry; and the same processes have been resorted to down to modern times. The best and most substantial walls are those *entirely of brick*, but being the most expensive as to material, lime, and work, such are very rare. The common mode is to build in alternate courses of brick and tufo—a coarse rotten-looking volcanic stone found everywhere in the Campagna, but which becomes harder on exposure to air. Wherever the wall is to be thick the sides only are done in this way, the centre being filled in 'a sacco,' as it is called, that is, with lime and fragments of stone, brick, and rubbish of every description. These walls are thickly coated with rough-cast externally."

"When a better appearance is required, for instance on churches, a facing of hewn travertine is applied to the basement story, and the mouldings of the upper stories are executed in the same material. The intervening wall-spaces being faced with coursed brick-work: this is rarely bound to the wall, and the Cancellaria, built by Bramante, is faced on the upper story with brick on edge; this work is called 'cortina.'"

Signor Bosio superintended, as clerk of works, the erection of the Braccio Nuovo, in the Vatican, and on that and other occasions had opportunities of examining the walls built by Alexander VI. and other pontiffs, to the time of Sixtus V. These walls are of the class which has just been described, and are generally executed in a careless and insufficient manner. "Roman masons always rely much on thick coats of rough-cast, or plaster, to cover the irregularities and defects of their work, and seem to have done so three hundred and fifty years ago; the impetuous spirit of Julius II., especially hurried works executed in his time; and to such an extent did this system prevail, that all the old foundations of the Vatican buildings are faulty. The ground which slopes towards the Tiber is of a yellow sand, on which these vast fabrics rest, and this sand is said to be ever moving downward, although at an imperceptible rate; later additions have been secured by piling, which, when the Braccio Nuovo was built, was carried to the great depth of seventy palms." The foundations of the older buildings are carefully watched, but still the walls have suffered, and this sufficiently accounts for the bulging of the plaster in the Stanze, whilst the inequality of the surfaces of these works is explained by Signor Bosio's account of the careless fabric of the walls.

Signor Colombo of Rome, who has much experience in early Italian art, has paid attention to this subject, and says that the Roman masonry, from the cottage to the palace, is the worst in Italy; he also says that in Lombardy the walls are frequently built of courses of brick and rubble.

The old practice of facing such walls as have just been described with brick, is continued in Rome, and as there is no bond whatever between the wall and this facing, it sometimes tumbles down in great masses; it is also very objectionable from the unequal settlement that frequently takes place. An example on a great scale is found in the walls of St Peter's, which, about eight French feet in thickness, are so built as to constitute in reality three walls, the outer one being travertine, the centre one tufo, and the inner facing brick; it is found that these settle separately, and as the building is already injured, it is watched with much care and anxiety.

As in this first part of my Report I have proposed to consider the state of old Italian frescos, with reference to the architectural construction only, I have dwelt at some length on modes of building, from which no danger is to be apprehended by the fresco-painter in this country. Where such remarkable carelessness as to the quality of the masonry has been exhibited, instead of being surprised at the present state of the frescos, we ought rather to wonder that they are preserved at all.

* By the expression "rubble walls," is here meant all walls chiefly built of irregularly formed stones, whether large or small, as well as other walls to be particularly described.

Wherever due attention has been paid to the construction of the walls, pictures either are in excellent preservation, or their dilapidation can be accounted for from external causes which might have been guarded against.

The houses at Genoa offer examples of a different description of rubble wall; they are built of masses of slate which, being hard and brittle, are rarely squared with the chisel, and there are not many examples of their being wrought into mouldings or other architectural ornamental features. The masses are large, which constitutes the difference between this kind of wall and those last described. All such walls are plastered externally and are generally painted in fresco, mouldings and other ornaments being represented in chiaro-scuro, and the flat part of the wall being painted red, yellow, or green. Some palazzi are decorated with external frescos of historical and allegorical subjects. Taking the constructive principle solely into consideration, the fresco-painting of Genoa upon this kind of wall has stood well; but whilst the examples of paintings on surfaces of this description are not numerous, walls so constructed are, like ashlar, liable to the objection of the damp condensing on the pictures in peculiar states of the atmosphere.

From the observations which have now been made it would appear that plaster will stand upon ashlar walls, especially if, as at Assisi, the stones be small and the seams open; but if the plaster be loosened from this kind of wall by damp or accident, it entirely falls away in large masses, showing that it does not adhere firmly to the masonry. It is not to be supposed that frescos will be again painted upon such defective walls as the rubble walls first mentioned, but it may be noted that the plaster does not fall from such in masses, but rather crumbles down.

It seems evident, from the examination of ancient frescos, that brick walls are the best for fresco, and the practice of the careful Germans and modern Italians are in favour of this opinion.

Frescos upon Lath.—There are many specimens of frescos upon lath in Italy; the most ancient is that of the "Trionfo della Morte," by Orgagna, in the Campo Santo of Pisa. The artist probably adopted the precaution from having entertained doubts as to the fitness of the walls of this edifice to receive frescos.

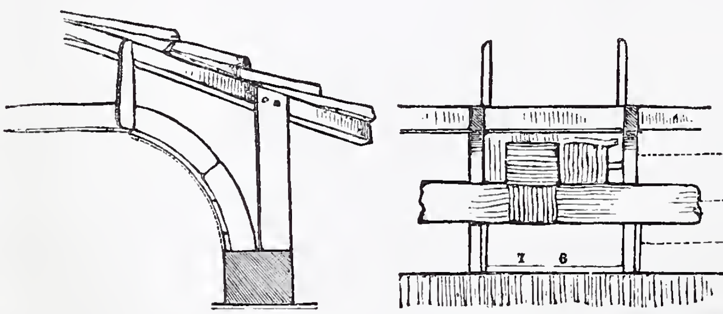
We read in Vasari that Giotto, when called upon to paint here, had the walls very carefully prepared; but his preparations were far from being sufficient, and his works, or those attributed to him, have nearly perished like most others in this celebrated edifice, that by Orgagna excepted, which is in good preservation. It is executed upon a lathing of reeds or stoja, as the Italians call it.* The lath in this case is probably merely nailed to the wall without the intervention of standards, as the surface of the fresco is even with those of its immediate neighbours. It has been supposed that the sea air injures frescos; this prejudice is a very old one, but is here disproved. Had it been the sea air, and not the damp in the walls that had injured these frescos, Orgagna's would have stood no better than the others. We may conclude from Orgagna's precaution that that able architect saw where the real danger lay, viz., the damp which rises from the soil or infiltrates from the roof.

The ceiling frescos in the upper Loggia of the Vatican by Giovanni da Udine† are upon stoja or lath: the wooden framing to which the lath is attached, is executed with a rudeness that would seem almost incredible, and these works have suffered severely from the original defective carpentry, and from neglect and damp. (See fig. 2.)

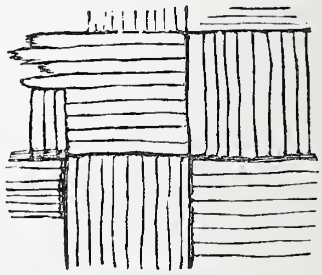
At Florence, in the Palazzo Vecchio, there is a chapel painted in fresco, by Bronzino, and the paintings on the ceiling, which are on lath, are in fine preservation, as are all the ceiling frescos in the public gallery of the Uffizj, executed in like manner upon lath or stoja. In the Palazzo Ducale at Venice there are some important frescos by Tintoretto upon a lathed ceiling, which are well preserved; and at the Villa Mazer, near Biadine, there are a number of frescos by Paul Veronese on what may be termed lath, although the construction is peculiar.

The construction of these coved ceilings is careful; the ribs which form the arches are of inch deal nailed together, as centerings are commonly made, so as to form ribs of two inches in thickness; these are thirteen and a-half inches deep, and are placed three feet apart: on the under surface are nailed laths of poplar three inches by one inch; these are fastened the broad way, and being kept a little apart an excellent key is given to the plaster. The lathing is plastered above as well as below; this is common also in all the framed ceilings which I saw in France, (those at Versailles may be quoted as examples.) The practice is an excellent precaution against injury to the works beneath from the accumulation of dust and dirt, as it is very easy to sweep and keep clean such places, and for the same reason it is advisable to plaster the upper surface of brick vaults, which was the practice of the Caracci, as exemplified in the Palazzo del Giardino at Parma.

Fig. 2.



Sketch of the Construction of the Terra Loggia of the Vatican.



Lathing Larger Scale.

From these various instances, it appears that frescos may safely be executed upon lath.*

The Mortar.—It is not possible to make many observations on the mortar on which mural pictures of the period before referred to are executed, as, fortunately, there are not a great number which are in such a state of dilapidation as to permit a particular examination of them in this respect. The majority of these pictures are painted, as is well known, upon an intonaco composed of lime and sand. It is evident that there was a diversity of opinion with regard to the quantity of sand to lime to be used, and the same diversity of opinion exists amongst the modern frescanti. From such examination as it was possible to make, it appears certain that those frescos have stood best in which it is apparent that there is a considerable proportion of sand in the lime; and I am disposed partly to attribute the bad state of the frescos by Correggio in the Duomo of Parma to his having used what is called a rich intonaco (that is, with a small proportion of sand), and the faintness of the colours is perhaps to be attributed to the same cause.

* This was ascertained by MM. Signol and Orsel, distinguished French artists, to whom I am indebted for the communication.

† These have just been restored, under the direction of the Cavaliere Agricola.

* I am not aware that there are, in any part of Italy, examples of frescos, executed upon any other kind of wall or preparation than those which have been described. I was at one time informed that the Aurora of Guido was executed upon a copper trellis; this I have since ascertained to be a mistake; it is on brick; but it is said that nails were driven to give the plaster a better hold, and this accounts for the spots, apparently of rust, seen on various parts of the picture.

A number of mural paintings are executed upon an intonaco formed of lime and marble dust; these however are not frescos but distemper pictures; that is, pictures which, although in many instances commenced in fresco, yet were finished in distemper. Pictures of this description are also found upon intonacos of lime and sand; and if at first the practice may have arisen from necessity, it appears to have been continued afterwards from choice, even after complete works in pure fresco had been executed.

The Signor Marini of Florence, an experienced fresco-painter, is of opinion that the pictures by Avanzi, in the chapel of S. Giorgio at Padua, are frescos. This artist flourished in 1370.* The mural works of Fra Beato Angelico and of Gozzoli are certainly commenced in fresco and finished in distemper. That they were commenced in fresco is proved by the existence of joinings in the plaster at certain intervals; but that they were not finished in the same manner is quite evident, for these joinings are at such a distance from each other that we must suppose the artist elaborately finishing several figures the size of life, or nearly so, in one day, which is manifestly impossible. This subject may be further considered in treating of distemper-painting.

There is nothing to be learnt apparently from old Italian plastering. In point of execution, it is surprising that such careless work could ever satisfy the artists. The Venetians have shown themselves in many instances clumsy plasterers beyond all others; the works of Pordenone especially exhibit the rudest workmanship, the surface being very uneven, and the joinings of the intonaco which mark the different days' work being very carelessly executed: such is also the case in the frescos of Titian.

The Germans carefully teach the propriety of making all cuttings and joinings in the plaster at outlines, where it is possible to do so; but some of the old masters paid little attention to this rule. Andrea del Sarto frequently makes joinings at some distance from the outline of a figure, following at the same time no other outline; and this he has evidently done to enable him to paint in a little of the background at the same time with the figure, and whilst it was wet. Gaudenzio Ferrari has adopted in some cases the same practice. At times we find in the works of the above and of other artists, joinings carried across limbs and other parts of pictures in a very awkward way, the result of carelessness and want of thought, and the effect is disagreeable. With the exceptions just mentioned, the rule of cutting at the outlines is supported by the practice of all schools.

The carelessness of the Venetian artists and plasterers has been adverted to; the Florentine practice is better, but still far from presenting in many of the early examples, sufficient attention to the preparation of the surface. If the wall was even, the plaster was made even, but if the wall was altogether the reverse, the plaster was allowed to be so also, and it is only in the works of later masters, that we find this workmanship so attended to as to secure an even surface: the frescos of Allori in S. Lorenzo and in the Palazzo Vecchio are models in this respect. It was the practice of Allori to make his cuttings at a very acute angle with the wall, which plan is however, with much reason, objected to in modern practice.† In Rome, it has been already noted, that the frescos by Raphael in the Stanze of the Vatican are, unfortunately, specimens of bad plastering; those by the same immortal artist in the Farnesina are much better in this respect.

The Cavaliere Agricola obligingly showed me some pieces of plaster from the ceiling of the third Loggia, painted by Giovanni da Udine, which, from their damaged condition, it had been impossible to retain in their places in making the repairs. These specimens exhibited three coats of plaster, differently prepared; the first (that next the lath) was of lime and coarse sand, and was one quarter of an inch thick; the next of the same thickness, was of lime and pozzolana; and the last, or intonaco, was of lime and marble dust, by no means very finely pulverized.

This corresponds with the arrangement in ancient examples, from which it is evidently imitated. In the Baths of Titus examples will be found of—first lime and coarse sand, one half-inch thick; then lime and pozzolana, of one inch in thickness, in which, however, there is an admixture of sand and pounded brick; the last and upper coat is of lime and pounded marble. It will be found that this, as regards the two last coats, is the identical preparation which is so commonly used in Italy for floors under the name of Venetian pavement, except that in the latter the fragments of brick in the substratum and the fragments of marble in the superstratum are much larger.

It is also quite plain, from the size of the fragments of marble in the specimens of ancient plaster, both in the Baths of Titus and at Pompeii, that the wall could not possibly be brought to a smooth surface either with the trowel or float; it must have been allowed to dry, and was then polished. It follows that in walls of this description the red, yellow, and other tints with which it was painted must have been subsequently applied, and had nothing of the nature of fresco, an art which, however, is apparently exemplified in ancient examples, for instance, in the Nozze Aldobrandini.

It may be generally stated, without adducing other examples of this period, that where the plastering is uneven, the ruin of the fresco, or its serious injury, is the result, whilst those frescos which have smooth and even surfaces will be found to be generally in good condition; and the most perfect specimens in point of workmanship and preservation are the frescos of the Caracci and of their scholars. These, in the majority of instances, are quite perfect, and may be quoted as triumphant specimens of the durability of this mode of painting.

* It is also the opinion at Florence that the still earlier pictures by Spinello Aretino in S. Miniato are frescos.

† It brings the lime or intonaco of the next day to so sharp an edge that it becomes difficult to spread it, and it is apt to dry too fast. The Germans cut at a much less acute angle, and the Florentines make the cut perpendicular to the wall.

EXPERIMENTS ON THE CORNISH ENGINES,

FOR ASCERTAINING THE QUANTITY OF AIR WHICH ENTERS THE FIRE-PLACES, WITH OBSERVATIONS THEREON.

By Robert Hunt, Esq.

It may appear easy to ascertain with tolerable correctness, the quantity of air which passes through fire-places constructed as those connected with the boilers of Cornish steam engines are. A few experiments, and a little consideration of the circumstances under which the combustion of the coal takes place, will show that the question is by no means one of easy solution. If the temperature of the air was uniform throughout the flues, from its first entrance into the fire-place, to its egress from the top of the chimney, its ascensional force might be calculated from the difference between the weight of the heated column, and one the same height at the observed temperature of the atmosphere. From this it would be exceedingly easy to calculate the quantity of air passing the fire-place in a given time. This uniform temperature does not, however, exist; and this alone, independently of the different density of the air previously to, and after it has undergone, combustion, renders every calculation at variance with experiment.

On the 29th of June, the external temperature being 72°, the thermometer stood in the cooling place of the large engine at Tresavean, 12 feet from the fire, at 87° Fahr.; 2 feet from it, at 90°; and 1 foot from the ash-pit, at 110°. In the flue, 30 feet from the fire, the thermometer indicated a temperature of 230°; whilst at the end of the flues, 101 feet from the fire, where the smoke enters the stack, the highest temperature obtained, was 190°. On the 13th of September, at North Roskear mine, the temperature of the air in the flue nearest the fire-place, was 340°; whilst at the bottom of the stack, 122 feet from the fire-place, the highest temperature obtained, was 234°. These results plainly show, how large an amount of refrigeration is going on during the passage of the aerial current through the flues and chimney. The expansion of air is uniform with the increase of temperature. The volume of air which at 32° is represented by 1·0000, expands at 212°, to 1·3750; and at 392°, to 1·7389. It has been found that hydrogen gas expands in the same proportion, from which it may be inferred that all gases expand to the same extent for equal increments of caloric. It might therefore be possible for any given chimney, by a series of carefully conducted thermometric experiments, to arrive at data by which the velocity of the aerial current might be calculated, and hence, the quantity of air passing the fires, arrived at. The

difficulties attending this mode of arriving at the required result, and the numerous liabilities to error, together with the impossibility of applying the results of experiments and calculations on one fire-place to any other, has induced me to pursue a different course.

It is necessary, in the first place, to ascertain the volume of air contained within the space between the fire and the top of the chimney. The following are the mean measurements of the flues, &c., of three important engines in this county:

I. The new engine at Tresavean.

	feet.
From the fire door to the ends of the flues,..........	101
Length of stack flue,..........	40
Height of stack,..........	60
	201

II. Taylor's engine, United Mines.

	feet.
From the fire door to the end of the flues,..........	107
Height of stack,..........	80
	187

III. West's Engine at North Roskear.

	feet.
Tube of Boiler,..........	37
Flues,..........	72
Between ends of boilers and stack,..........	12
Stack,..........	90
	211

Having been furnished by Mr West, with the correct measurements of all the spaces in the flues and chimney at North Roskear, I am enabled to calculate with tolerable correctness, the capacity of all the parts occupied by the aerial current. The following is the result:—

	cubic feet.
Flue through tube, taking 1 foot off 37 for ash-pit,— $36 \times 4 \times 4 \times (\cdot 7854 = \frac{3}{4}) = 432$ feet, then three boilers,	1296
Flue over one boiler, $36 \times 9\frac{1}{2} \times 7$ inches $= 199$, and three of them,..........	597
Flue under one boiler, $36 \times 10\frac{1}{2} \times 1\frac{1}{2} = 567$, and three of them,..........	1701
	3594
Between boiler and stack, $12 \times 2\frac{1}{2} \times 1\frac{1}{2}$,..........	45
Ditto to other damper,..........	45
Stack, $90 \times 3 \times 3 \times (\cdot 7854 = \frac{3}{4}) =$..........	607
	4291

Hence we approximate very nearly the truth, when we consider the space occupied by the air, as being 4291 cubic feet; which at 60° of Fahr. and the barometer at 30 inches, would be equal to 328 pounds avoirdupois nearly. This of course requires to be corrected for the expansion due to the elevated temperature of the flues. I have before stated the ratio of the expansion of the gases. Hence, we find, 32° giving volume of unity, that the volume due to 60°, would be 1·05;—again, if we take 250° as the average temperature of the flues and stack, which will be found to be pretty nearly the truth, the volume will be as 1·44. Consequently, 4291 feet above, of this rarefied air, and must be reduced as 1·44 to 1·05, which will give us 3119 feet, or 238 lbs., of air, as the quantity contained at any given time, at the above temperature, in the flues and chimney of the Engine at North Roskear Mine.

It must, however, be remembered, that the whole of this volume is not due to the atmospheric air, a portion of it being made up of the volatile matters which pass off unconsumed from the coats themselves.

It appears that at the United Mines, where there are five fire-places, about 4284 lbs. of coal are consumed in the twenty-four hours. This quantity of coal, I find by experiment, will yield about 27,000 cubic feet, gas. This gas consists of

8 measures of carburetted hydrogen,
1 ditto olefiant gas,
1 ditto carbonic oxide.

The products of the combustion of these gases are as follows.

The carbon vapour combines with one portion of the oxygen to form carbonic acid, and the hydrogen with another to form water, which escapes as steam, the contents of the flues and chimney being nitrogen, carbonic acid, steam, and a portion of uncombined oxygen, as will be seen hereafter.

Experiment has proved to me, that the time occupied by the passage of the volume of vapour in the flues through their whole length is, the temperature being 70°, and the atmospheric pressure 30 inches, nearly two minutes. The difference in the time taken by a dense smoke generated by damp coal, and by oil of turpentine on tow, in passing from the fire-places out of the chimneys of the three mines above named, varied but a few seconds. The experiments were repeated several times at each mine, on different occasions, with results nearly corresponding with each other. Now, in two minutes, according to the data given me at the United Mines, six pounds of coal are consumed. These on the average yield 21·3 cubic feet of carburetted hydrogen gas, and produce, with the oxygen of the air, during combustion, 55·9 of carbonic acid and some carbonic oxide, while its hydrogen combines with other portions of oxygen to form water. If we take into account the circumstance that the specific gravity of carbonic oxide and of oxygen are different, and that this gas is expended in the same ratio as is above named, we must reckon the aerial matter formed by the coals every two minutes, at about 30 cubic feet; hence the 3119 feet will be reduced to 3089 feet of air as the quantity. I am, however, satisfied, that the nitrogen and oxygen found in most kinds of coal, and the interruption to the efflux by counter currents, &c., compels us to reduce even this to 3000 feet, as the nearest approach to which we can arrive of the amount of atmospheric air passing through the flues in every two minutes of time; being a weight equal, at the mean pressure and temperature, to about 220 lbs. avoirdupois, or nearly three tons of air per hour.

It will now be necessary that I should give a summary of the various experiments tried, for the purpose of elucidating this question, and thus furnish the required data for proving the correctness or otherwise of the foregoing statement. I must here acknowledge the great readiness with which Mr Loam and Mr West permitted the trials to be made, and with which they rendered me every assistance I required in the experiments.

Tresavean Engine, June 29th.

Working two strokes a minute.
Duty 70,000,000.
Temperature 72°, Barometer 30·52.

At the end of the flues, 101 feet from the fire, the thermometer rose to 190° in twenty-five minutes.

Repeated immersions of the instrument in this atmosphere produced no further elevation of temperature.

In the flue nearest the fire, about 30 feet from it, the thermometer indicated 200°.

As the fires were burning very low and everything much damped down, I was desirous of trying the effect of an increase of the draft; the dampers being but a little opened, the thermometer rose in a few minutes to 230°.

Mr Loam made an experiment in a whim engine, by placing the thermometer in a cylinder of oil in the flues, which gave

32 feet from the fire, 460°.
47 ditto 370°.

From the superior temperature indicated by a thermometer having a metallic scale, over that given by one having a boxwood scale, under all circumstances, this last experiment requires a slight correction.

It was found that a dense smoke made in the fire place, required, before it passed to the top of the chimney, 1′ 50″—1′ 55″—2′—1′ 52″.

Same Engine, August 24th.

The results at this time differed but slightly from those given above.

North Roskear, August 24th.

A series of experiments were tried, but more definite results were arrived at on September the 13th.

Working $4\frac{3}{4}$ strokes a minute.
Pressure between 30 lbs. and 40 lbs. to the inch.
Thermometer at 70°. Average height of barometer, 30·25 inches.

At the end of the flues, 122 feet from the fire, the temperature was 234°, damper open. The damper half closed, 220°.

Close to the fire, 320°, Ditto 330° } Damper Open.
Ditto 340° Damper half closed.

Here we see the effect of the damper in checking the current, and accumulating more heat in the flues next the tube.

Several experiments gave rather more than two minutes for the smoke to reach the top of the stack; all the circumstances in this instance being most favourable, I regard these results as most satisfactory.

TAYLOR'S ENGINE, UNITED MINES.

Working 5 strokes per minute.

Pressure 35 lbs. to the inch. Duty nearly 100,000,000.

Temperature 58°. Barometer (near) 29·94.

Temperature of the flues, 310°

Ditto 330°

The smoke took from 1′ 40″ to 2′, in passing from the fire-place to the top of the stack.

Samples of air have been collected on five different occasions from the flues of these engines. It is but right that I should state that the air was collected by means of a tube inserted through the brick-work, and carefully cemented in, to prevent the ingress of air. From this tube it was pumped by a condensing syringe, into a caoutchouc bag, from which it was, as soon as possible, removed into stoppered bottles, and analyzed within a few hours.

After trying a great many eudiometric experiments for the purpose of ascertaining the real quantity of oxygen contained in the air, I was induced to abandon both the method with the nitric oxide, and by electricity, for phosphorus ignited by means of a burning glass, in measured volumes of the air, confined in a graduated tube over water. The result was, in each case, tested by the slow oxidation of the phosphorus. By these methods I was enabled to detect with greater precision any inflammable gases which had escaped combustion.

The following are the amounts of oxygen detected in equal volumes of air, corrected to the mean temperature and pressure.

Thirty cubic inches of air, after the carbonic acid had been absorbed by caustic potash,* from the air taken from the nearest flue of the large engine at Tresavean, gave..... 3·01
Ditto from the flue nearest the stack .... 3·
Ditto collected at second experiment from the nearest flue 2·98
Ditto from the nearest flue from the engine at North Roskear.. 3·20
Ditto from North Roskear, collected at the time of second experiment.. 3·07
Ditto from the end flue of Taylor's engine at the United Mines.. 2·75

The carbonic acid was absorbed in each case.

The proportion of the oxygen to the nitrogen in atmospheric air is about one-fifth; from this we see the quantity consumed by the fire, or, in other words, which has entered into combination with the carbon vapour and the hydrogen, to form carbonic acid and steam.

In each of the samples of air, about $\frac{1}{150}$th part of carburetted hydrogen and olefiant gas was detected; less in the air from Tresavean, where the combustion was exceedingly slow, than in any of the others.

The action of the lungs in the animal system on the atmosphere, bears the closest possible analogy to the phenomenon of combustion in a common furnace fire; the only difference between them being that of slow chemical combustion in the one case, and rapid combination in the other. If we examine the air which we respire, it will be found to contain still a sufficient quantity of oxygen to support the combustion of highly inflammable bodies. It needs no argument to prove the difficulty of supporting life in an atmosphere from which a portion only of the oxygen is abstracted. It is quite impossible for any animal to exhaust an atmosphere of all its oxygen. If we enclose a lighted taper in a quantity of air, it will be in a short time extinguished, from the deficiency of oxygen. Sulphur will, however, continue to burn in the atmosphere which was insufficient to support the taper; and even the sulphur cannot abstract the last portions of oxygen, a sufficient dose being still left to admit of the combustion of phosphorus for a brief space.

This experiment will show the necessity of allowing such a quantity of air to be admitted to the fire-place, as will ensure the complete combustion of the gases formed, and for this an excess is necessary; this excess must, of course, be found in the flues, and it appears to me that the fires in each instance have been so regulated, that just sufficient air has been admitted to produce the best possible effects. If less air was admitted, the fires would be distressed; and if a larger quantity, it would, in all probability, exert a cooling influence, which would diminish the duty in proportion to the coals consumed. From the information I have received from several intelligent engineers, I gather that the effect has been a falling off in the duty of the engine, whenever the quantity of air admitted has been increased. Experience has convinced our practical engineers that the best duty is done when every aperture, through which strong currents might find their way, is closed up, and just sufficient air admitted by the ash-pit, to support a moderate, but not a quick, fire.

* The amount of carbonic acid averaged 1 inch in 9 inches.

MODES OF VENTILATING GAS AND OIL LAMPS.

I.—ON THE VENTILATION OF LAMP-BURNERS IN DWELLINGS AND HALLS OF ASSEMBLY.

IN an interesting paper by Professor Faraday, he states that his attention was first drawn to the subject embraced under this head, in consequence of the injury sustained by the books of the library of the Athenæum Club, and the complaints made by the members, himself among others, of the vitiated state of the air in the rooms. These evils led him to suggest the trial of various plans for effecting the removal of the products of combustion, and for the ventilation of the lamp-burners; and finally decided on that to be described as the simplest and most effectual.

Considering the question philosophically, the Professor correctly assumed that all substances used for the purpose of illumination, might be represented by oil and coal-gas; for, although tallow and wax are also employed for that purpose, they cannot be burned until they are rendered fluid like oil; they may therefore for all practical purposes be classed with it.

Again: oil and gas both contain carbon and hydrogen, and it is by the combination of these elements with the oxygen of the air that light is evolved. The carbon produces carbonic acid, which is deleterious in its nature, and oppressive in its action, in closed apartments, and the hydrogen produces water. A pound of oil contains about 0·12 of a pound of hydrogen, 0·78 of carbon, and 0·1 of oxygen; when burnt it produces 1·06 of water, and 2·86 of carbonic acid, and the oxygen it takes from the atmosphere is equal to that contained in 13·27 cubic feet of air. A pound of London coal-gas contains on an average 0·3 of hydrogen, and 0·7 of carbon; it produces, when burnt, 2·7 of water, and 2·56 of carbonic acid gas, and consumes 4·26 cubic feet of oxygen, which is equal to the quantity contained in 19·3 cubic feet of air.

A pint of oil when burnt produces a pint and a quarter of water; and a pound of gas, more than two and a-half pounds of water; the increase of weight being due to the absorption of oxygen from the atmosphere, one part of hydrogen taking eight parts (by weight) of oxygen to form water. A London argand gas lamp, in a closed shop window, will produce in four hours two pints and a half of water. A pound of oil also produces nearly three pounds of carbonic acid, and a pound of gas two and a-half pounds of carbonic acid. For every cubic foot of gas burnt, rather more than a cubic foot of carbonic acid is produced. As carbonic acid is a deadly poison, an atmosphere containing even one-tenth of it is fatal to animal life. The various accidents from lime and brick-kilns, brewers' vats, occasionally from the sinking of wells, and from the choke damp in coal mines, attest the danger contingent upon the presence of this substance. A man breathing in an atmosphere containing seven or eight parts of carbonic acid, would suffer, not from any deficiency of oxygen, but from the deleterious action of the carbonic acid. From the researches of physiologists, it indeed appears that a certain amount of carbonic acid, (the choke damp of the miner,) is requisite to stimulate the action of the heart, and regulate the circulation of the blood; but nature itself has made provision for keeping up the proper supply. We have more than once had occasion to illustrate this doctrine in our pages, and therefore need not insist upon it here.

M. Leblanc has recently analyzed carefully the confined air of inhabited places, and concludes, that the proportion of carbonic acid gas in such places may be regarded as measuring with sufficient exactness the insalubrity of the air; that in the proportion

of 1 part to 100 of air, ventilation is indispensable for the prevention of injury to the health; that the proportion of carbonic acid gas should not exceed a five-hundredth part, though it may extend without inconvenience to a two-hundredth part. If a room twelve feet square and twelve feet high, with the doors, windows, and fire-place closed, has a gas lamp burning in it, consuming five cubic feet of gas per hour, the light will produce sufficient carbonic acid, in rather more than three hours, to be in the proportion of one part to 100 of air, and, as M. Leblanc states, when in such condition, the air is decidedly injurious to health: and even in one hour and a-half, it will produce that portion of carbonic acid which he considers should never be exceeded.

With a lamp burning in the ordinary way, the products of the combustion flow into the apartment, and the modes of ventilation by ascension only partially remedies this evil. In the experiments instituted by Professor Faraday in connexion with the case to which his attention was first attracted, he found that there was sufficient draught in the main part of the metal chimney to allow of a *descending* current over the lamp; and in order to take advantage of this circumstance, he made the tube to turn short over the edge of the glass, instead of going directly upwards, to descend to the arm or bracket, and passing along it, to ascend at the central part of the chandelier, and against the wall when applied to a single lamp. But this modification of the ordinary mode of ventilation by ascension was still found ineffectual, and was speedily replaced by the following simple mode of ventilating, which, it may be observed, is nothing more, strictly considered, than a correct practical application of the principle of a descending draught to a lamp-burner. The gas-light has its glass chimney as usual, but the glass-holder is so constructed as to sustain not merely the chimney, but an outer cylinder of glass larger and taller than the first; the glass-holder has an aperture in it, connected by a mouthpiece with a metal tube, which serves as a ventilating flue, and which, after passing horizontally to the centre of the chandelier, there ascends to produce draught and carry off the burnt air.

The mechanical arrangement of the apparatus and the principle involved, will readily be understood from the accompanying diagrams and description. These, it is necessary to remark, are derived chiefly from the specification of a patent granted to Mr Robert Faraday, Gas-Fitter, Wardour Street, Soho, to whom Professor Faraday (his brother) has transferred his right to the improvements.

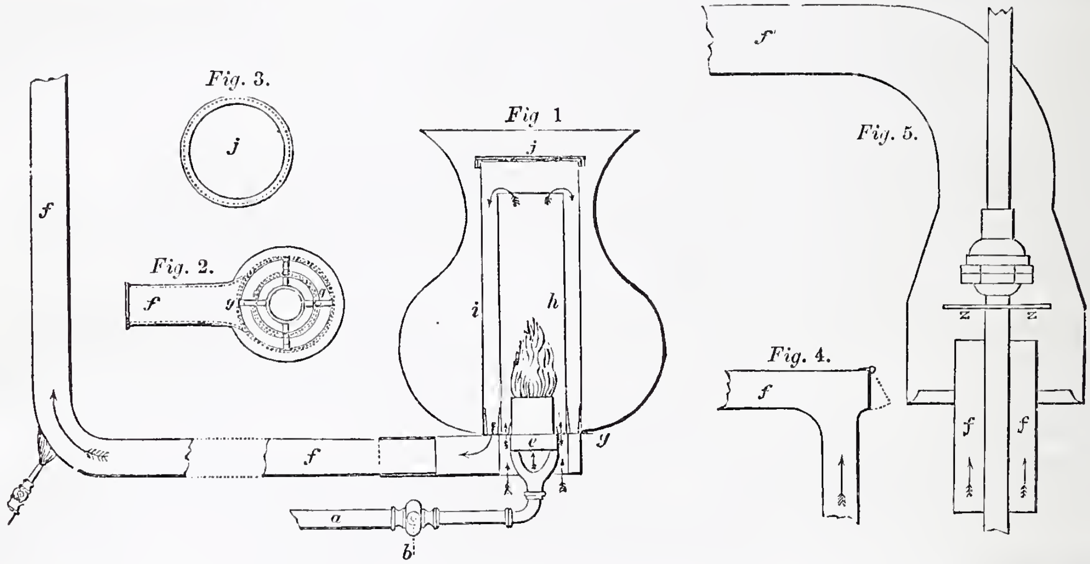


Fig. 1 shows the general arrangement of the gas-burner and its ventilating appurtenances. *a* is the supply-pipe from the gas-main, with a stop-cock at *b*; and *e* an argand burner—all of the ordinary construction. Instead of this apparatus for burning gas, it is easy to conceive the substitution of a lamp for burning oil; the arrangement of the other parts would not be in any manner affected by the kind of material used in combustion. *f f* is a metal tube, through which the products of combustion are conveyed away from the burner. The burner is enclosed by an ordinary glass chimney *h*; this is surrounded by another glass cylinder *i*, closed at top by a plate of mica *j*, (shown in plan fig. 3,) or, what is considered better, by two plates of mica, one resting on the top of the glass, and the other one dropping a short way within it, the two being connected together by a metal screw and nut, which keeps them a little apart; thus forming a stopper which cannot be shaken off, but may easily be lifted on and off by a small metal ring or knob, fixed upon the upper plate. The glass cylinders, with the ground glass globe *g*, are supported upon the glass holder in the ordinary way. The arrangement is shown in plan fig. 2.

By this disposition, the air is allowed admission to the flame by a passage between the inner glass cylinder or chimney and the burner; but the products of combustion having no passage of escape upward, descend between the glasses, and pass into the tube chimney *f f*, by which they are led out of the apartment, as indicated by the arrows.

In some cases, it has been found in small rooms, that the sudden shutting of a door has created a partial vacuum, and that the air has tended to return through the flue tube *f f*. In order to prevent this, a light valve (fig. 4,) is applied to the passage opening into the room, so that the force of the air may be expended in overcoming the valve, instead of passing through the flue-tube as far as the burner. The rush of air so occasioned may also be prevented from going to the burners, by means of a deflector as shown in fig. 5, where *f f* denotes the passage for the products of combustion, and *f'* is a continuation of that passage; *z z* is a stop which deflects off any sudden rush of air from the pipe *f'*, so that it does not enter the pipe *f f*, whilst the draught ordinarily in this last will carry off the gaseous products to the pipe *f'*.

In some cases, also, where the flue-tubes would require to be very long and horizontal, they are simply led into the chimney of the apartment, in order to take advantage of the draught in it; or a fan may be employed to obtain the requisite draught.

In ordinary cases, when advantage is not taken of the fire-chimneys to obtain the necessary draught in the flue-tube on lighting the lamp, the pipe is slightly heated at some part of its length to rarefy the air within, and thereby to commence the current. The application of a flame for that purpose is shown on the left in fig. 1.

Professor Faraday, on the occasion of describing this arrangement at the Institution of Civil Engineers, observed, that the additional apparatus necessary for the purpose of producing the end required, is not objectionable in architectural appearance; that the ventilation of the lamp is perfect; the light increased from 10 to 20 per cent.; the heat given to the rooms modified; and additional safety from accidents obtained, as in the event of any leakage from the pipes, or from a gas-cock being inadvert-

ently left open, the gas, instead of mixing with the air of the room and becoming explosive, would be carried off by the metal tubes.

He also illustrated the principle of the invention by several experiments; first demonstrating that, if a lighted taper was applied to the top of a lamp chimney it would be instantly extinguished, or a glass jar held over it would be immediately filled with air, in which a light could not burn or any animal exist. If a portion of lime water was poured into the jar it became turbid in appearance, owing to the precipitation of the carbonate of lime, formed by the combination of the carbonic acid with the lime. The sulphurous and sulphuric acids also contained in the water, resulting from the combustion of coal gas, were injurious to metals and to articles of furniture. He then explained that at his suggestion, the gas lights of the chandelier in the Library of the Athenæum were ventilated by tubes dipping into the lamp glasses, and conjoining at a short distance above into one central pipe, which carried away all the burnt air from the room.

In a conversation which ensued, Mr Bethell remarked, that the inner chimney appeared to become dim after the light had burned some time. Professor Faraday explained that this might arise from several causes; he apprehended it was chiefly occasioned by the action of the sulphur in the coal gas upon the ingredients of which the glass chimney was composed. In oil lamps the same effect was observed, but not so speedily as with coal gas. The Trinity House suffered much by it, and had made experiments on various qualities of glass for the chimneys of the lamps of lighthouses. Chimneys formed of mica would not be so affected, but they were not so transparent as glass.

Mr Bethell said that the Bude light, as now used in the House of Commons, was constructed somewhat on the same principle as had been described in the paper, except that the current was directly upward, which rendered the application of two chimneys unnecessary: perfect ventilation was obtained by it.

Professor Faraday said that the Bude light, as proposed to the Trinity House, was an oil lamp, supplied with oxygen by an apparatus for generating it. In lighthouses it was indispensable that the lamps should be so arranged that the lights should consume only a given quantity of oil, and retain an unvarying degree of brightness for a given time, which was now four hours, at the end of which time they were trimmed. It was found that with the Bude light, the quantity of oil consumed was greater, and the lamps required trimming in two hours, in consequence of the wicks charring; these circumstances rendered the system inapplicable to lighthouses. Subsequently, five of the Bude light lamps had been referred to him by the House of Commons for experimental purposes, and his observations upon them were of the same nature.

II.—On the Ventilation of Lighthouse Lamps.

At the meeting of the Institution of Civil Engineers, at which the arrangement for the ventilation of lamps in dwellings was described, Professor Faraday further stated that his attention had been directed to the subject also by the disadvantages attendant upon the want of ventilation in the lanterns of lighthouses, as in consequence of the condensation of the products of combustion upon the windows, the intensity of the light was diminished to a serious extent, and the quantity of carbonic acid in the lanterns was at times so great that the keepers could with difficulty enter them. This was illustrated by an experiment, showing the difference between allowing combustion to give its products to the air of a room, and carrying off those products freely to the exterior. A short wax candle was placed burning on a plate, a glass jar put over it, and the upper aperture of the jar closed by a globular cork, through which was passed a piece of glass tube, about half an inch in diameter, and twelve or fourteen inches long—the tube descending to the top of the candle flame, and being placed just above it. Under these circumstances, plenty of air passed into the jar between its edges and the plate, and out by the tube, to supply all that was needed for combustion, and to keep the glass chamber clear: therefore, in that position it would burn for any length of time, and the jar remain quite bright. But on moving the cork a little, so that the tube should no longer be over the flame, all these results changed, though the air-ways remained exactly as before. The candle then gave the products of its combustion to the general air of the glass chamber which immediately became dull, from the water deposited upon it; the air itself was deteriorated; the light grew dim, and in a few minutes it went out; but if that was prevented, by the tube being again placed over it, signs of recovery appeared; the light resumed its former brightness, and after a short time even the dew disappeared from the glass, demonstrating how indispensable a perfect ventilation was for lighthouses.

In this paper the author states that the fuel used in lighthouses for the production of light is almost universally oil, burnt in lamps of the Argand or Fresnel construction; and, from the nature and use of the buildings, it very often happens that a large quantity of oil is burnt in a short time, in a small chamber exposed to low temperature from without, the principal walls of the chamber being only the glass through which the light shines; and that those chambers being in very exposed situations, it is essential that the air within should not be subject to winds or partial draughts, which might interfere with the steady burning of the lamps.

If the chamber or lantern be not perfectly ventilated, the substances produced by combustion are diffused through the air, so that in winter, or damp weather, the water condenses on the cold glass windows, which, if the light be a fixed one, greatly impairs its brilliancy and efficiency, or, if the light be a revolving one, tends to confound the bright and dark periods together. The extent to which this may go, may be conceived, when it is considered that some lighthouses burn as much as twenty, or more, pints of oil in one winter's night, in a space of 12 or 14 feet diameter, and from 8 to 10 feet high, and that each pint of oil produces more than a pint of water; or, from this fact, that the ice on the glass within, derived from this source, has been found in some instances an eighth, and even a sixth, of an inch in thickness, and required to be scraped off with knives.

The author's plan is to ventilate the lamps themselves by fit flues, and then the air inside the lantern will always be as pure as the external air, yet having closed doors and windows, a calm lantern, and a bright glass.

In lighthouses there are certain conditions, to which the ventilating arrangement must itself submit, and if these are not conformed with, the plan would be discarded, however perfect its own particular effect might be. These conditions are chiefly, that it should not alter the burning of the oil or charring of the wicks—that it should not interfere with the cleaning, trimming, and practice of the lamps and reflectors—that it should not obstruct the light from the reflectors—that it should not, in any sudden gust or tempest, cause a downward blast or impulse on the flame of the lamp—that, if thrown out of action suddenly, it should not alter the burning; and, added to these, that it should perform its own ventilating functions perfectly.

Lighthouses have either one large central lamp, the outer wick of which is sometimes $3\frac{3}{4}$ inches in diameter, or many single argand burners, each with its own parabolic reflector. The former is a fixed lamp; the latter are frequently in motion. The former requires the simplest ventilating system, and is thus described:—

The ventilating pipe or chimney is a copper tube, 4 inches in diameter, not, however, in one length, but divided into three or four pieces: the lower end of each of these pieces, for about $1\frac{1}{4}$ inch, is opened out into a conical form about $5\frac{1}{2}$ inches in diameter at the lowest part. When the chimney is put together, the upper end of the bottom piece is inserted about $\frac{1}{2}$ an inch into the cone of the next piece above, and fixed there by three ties or pins, so that the two pieces are firmly held together; but there is still plenty of air-way, or entrance, into the chimney between them. The same arrangement holds good with each succeeding piece. When the ventilating chimney is fixed in its place it is adjusted, so that the lamp-chimney enters about half an inch into the lower cone, and the top of the ventilating chimney enters into the cowl or head of the lantern.

With this arrangement it is found that the action of the ventilating flue, is to carry up every portion of the products of combustion into the cowl; none passes by the cone apertures, out of the flue into the air of the lantern, but a portion of the air passes from the lantern by these apertures into the flue, and so the lantern itself is in some degree ventilated.

The important use of these cone apertures is, that when a sudden gust, or eddy of wind, strikes into the cowl of the lantern, it should not have any effect in disturbing or altering the flame. It is found that the wind may blow suddenly in at the cowl, and the effect never reach the lamp. The upper, or the second,

or the third, or even the fourth portion of the ventilating flue might be entirely closed, yet without altering the flame. The cone junctions in no way interfere with the tube in carrying up all the products of combustion; but if any downward current occurs, they dispose of the whole of it into the room, without ever affecting the lamp. The ventilating flue is, in fact, a tube which, as regards the lamp, can carry everything *up*, but conveys nothing *down*.

In lighthouses with many separate lamps and reflectors, the case is more difficult and the arrangement more complicated, yet the conditions before referred to are more imperatively called for, because any departure from them was found to have greater influence in producing harm. The object has been attained thus:—A system of gathering pipes has been applied to the lamps, which may be considered as having the different beginnings at each lamp, and being fixed to the frame which supports the lamps, is made to converge together and to the axis of the frame by curved lines. The object is to bring the tubes together behind the reflectors, as soon as convenient, joining two or more into one, like a system of veins, so that one ventilating flue may at last carry off the whole of the lamp products. It is found that a pipe $\frac{7}{8}$ths of an inch in diameter is large enough for one lamp; and where, by junction, two or more pipes have become one, if the one pipe has a sectional area, proportionate to the number of lamps which it governs, the desired effect is obtained.

Each of the pipes $\frac{7}{8}$ths of an inch in diameter, passes downward through the aperture in the reflector over the lamp, and dips an inch into the lamp-glasses; it is able to gather and carry off all the products of combustion, though, perhaps, still 2 inches from the top of the flame, and therefore not interfering in any respect with it, nor coming as a shade between it and any part of the reflector: the flame and reflector are as free in their relation to each other as they were before. Neither does this tube hide from the observer or mariner, a part of the reflector larger than about $1\frac{1}{2}$ square inch of surface, and it allows of a compensation to two or three times the amount; for, when in its place, all the rest of the aperture over the lamp, which is left open and inefficient in the ordinary service, may be made effectual reflecting surface, simply by filling it up with a loose, fitly formed, reflecting plate.

At this termination of the ventilating flue an important adjustment is effected. If the tube dip about an inch into the lamp-glass, the draught up it is such that not only do all the products of combustion enter the tube, but air passes down between the top edge of the lamp-glass and the tube, going, finally, up the latter with the smoke. In this case, however, an evil is produced, for the wick is charred too rapidly; but if the ventilating flue descends until only level with the top of the lamp-glass, the whole of the burnt air does not usually go up it, but some passes out into the chamber, and at such times the charring of the wick is not hastened. Here, therefore, there is an adjusting power, and it was found by the trials made, that when the tube dipped about half an inch into the lamp-glass, it left the burning of the lamp unaltered, and yet carried off all the products of combustion.

The power already referred to, of dividing a chimney into separate and independent parts, and yet enabling it to act perfectly as a whole, as shown in the single central chimney, was easily applicable in the case of several lamps, and gave a double advantage; for it not only protected the lamps from any influence of down draught, but it easily admitted of the rotation of the system of gathering flues, fixed to the frame sustaining the lamps and reflectors in a revolving lighthouse, and of the delivery of the burnt air, &c., from its upper extremity into the upper immovable portion of the flue. This capability in a revolving light is essential; for in all, the support of the frame-work is of such a nature, as to require that the upper part of the flue should be a fixture.

The author explains that it is as an officer of the Trinity House, and under its instructions, that he entered into the consideration of this subject: that, as to the central chimney, its action has been both proved and approved, and that all the central lights are ordered to be furnished with them; that as respects the application to separate and revolving lamps, the experiment has been made under the direction of the Trinity House, on a face of six lamps, being a full-sized copy of the Tynemouth revolving light, and, so far to the satisfaction of the Deputy Master and Brethren, that the plan was applied immediately to two light-houses which suffered most from condensation on the glass; we believe it has been attended with full success.

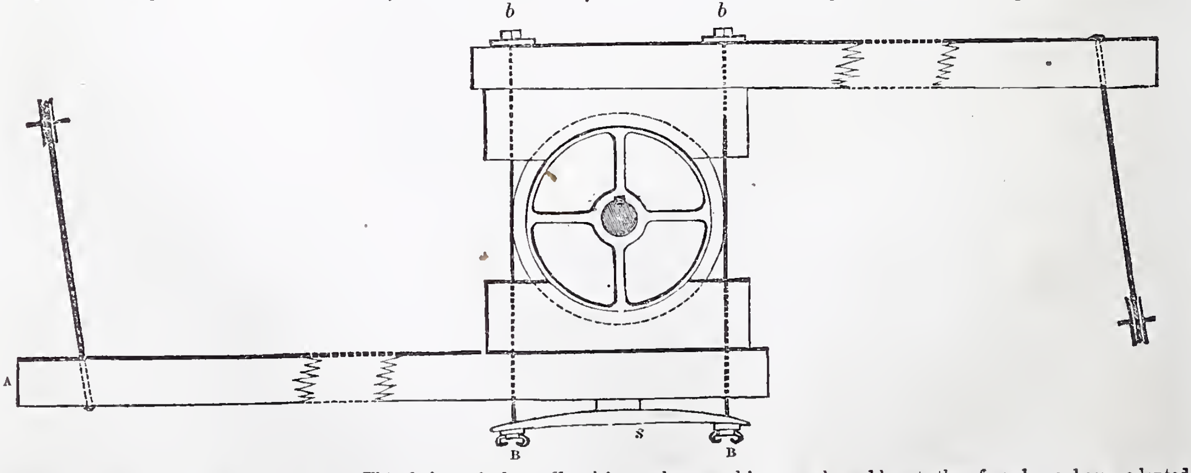
M. DE PRONY'S FRICTION DYNAMOMETER OR BRAKE.

ARTICLE II.

MODIFIED FORMS OF THE BRAKE AND METHOD OF CALCULATING THE RESULTS OBTAINED BY IT.

We have already described the form of brake used by M. Morin in testing the power of vertical water-wheels, and that form may be regarded as generally applicable when the shaft upon which the brake is to be placed, has the horizontal position. But when the brake is to be applied to a vertical shaft, a slight modification in the arrangement becomes necessary. In that case the scale-pan must be attached to the arm of the brake by a chain or cord passing over a pulley; and in order to obtain a better adjustment, and avoid unequal strain upon the shaft, it is of advantage that the brake have two arms, as represented in plan by the annexed diagram.

The brake is here supposed to be placed upon an iron shaft,



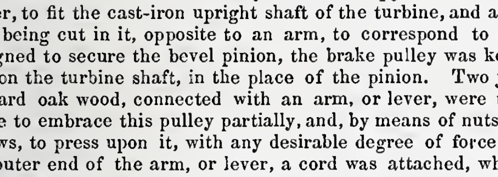
to which the eye of the pulley is fitted. This fixing of the pulley does not, however, readily allow of the brake being used in testing other machines, and could not therefore have been adopted by M. Morin, who was in consequence necessitated to use ad-

justing screws in centering the pulley upon the shaft. The form of this brake also differs from that employed by M. Morin, in having two arms, and two friction blocks, bearing against the periphery of the pulley, instead of the articulated band employed by him. The friction blocks are of wood, and are bound together by the screwed iron rods *b b*, which have simple nuts at *b b;* but at B B the ends pass through a spring S, and have hand-nuts by which the pressure of the blocks upon the pulley may be adjusted at pleasure. The spring also promotes the more steady working of the brake when in operation.

This form of brake is not, however, uniformly adopted; we have rarely seen any other applied to vertical shafts, and have uniformly employed it in experiments over which we had control: but it is often constructed with one arm only, and without the spring S. In Tredgold's work on the Steam Engine, p. 270, we find the one-armed brake described and figured without any notice of the inconvenience attending its application in that form to vertical shafts. In America also, it seems to be restricted to a single arm. In a paper by Mr Ellwood Morris, in the *Journal of the Franklin Institute*, of recent date, and to which we were indebted in our former article, the author gives a description and figure of a brake which would be accurately represented by removing the arm A, and spring S, from that depicted above, and by placing nuts similar to those at *b b*, upon the binding-rods, directly against the friction block. The brake was constructed under his own directions, for the purpose of testing the power of a turbine erected by Merrick and Towne of Philadelphia, to drive a cotton mill at Rockland in Delaware. The instrument "consisted of a turned cast-iron wheel, or pulley, four inches broad upon the face, with a ring five-eighths of an inch thick, supported by four arms, and having a flanch about half an inch thick, and say one inch wide, projecting from one margin; the eye of this wheel was accurately bored out $4\frac{5}{16}$ inches in diameter, to fit the cast-iron upright shaft of the turbine, and a key seat being cut in it, opposite to an arm, to correspond to that designed to secure the bevel pinion, the brake pulley was keyed fast on the turbine shaft, in the place of the pinion. Two jaws of hard oak wood, connected with an arm, or lever, were then made to embrace this pulley partially, and, by means of nuts and screws, to press upon it, with any desirable degree of force; to the outer end of the arm, or lever, a cord was attached, which, being conducted in a proper direction over a small fixed pulley, had suspended from it, by slender hooks, the weights which determined the power exerted by the turbine upon the brake pulley, and consumed by it in friction against the wooden jaws, or cushions."

When this brake was first applied, Mr Morris states that he experienced considerable difficulty in obtaining regularity of friction, as neither the faces of the pulley nor of the friction blocks were perfectly smooth. His mode of overcoming this difficulty was simple, and may be imitated when imperfect workmanship renders it necessary. He allowed "the brake pulley to run under the action of oil and emery, and with a considerable friction from the jaws, until all the surfaces of contact were ground quite smooth."

The calculation of the results obtained by the brake is exceedingly simple. In our former article, we gave the rule in the form of an algebraic formula, but intimated that no further knowledge of numbers is required than is possessed by every person acquainted with the elementary rules of arithmetic. The principle may be made obvious by means of the following diagram, which we may take to represent the application of the



brake to any shaft. Then it is clear that the resistance overcome by the machine is the same as if the weight P upon the arm of the brake, were raised by a drum of which the radius is C F, that is, *c f*. It is therefore also plain, that by multiplying the length C F into the weight P, in lbs., and by the number of revolutions of C per minute, and by the number 6·2832 (that is, twice 3·1416, it being a circumference which is considered), the result will be the lbs. raised 1 foot high per minute; and the result being divided by 33000, is the horse power according to the ordinary estimate. Thus suppose the shaft C to make 100 revolutions a minute, the length of the arm between the centres of action, that is, the effective length C F, to be 10 feet, and that a weight of 200 lbs. is required to balance the power of the machine. Thus then we have

$100 \times 10 \times 6{\cdot}2832 \times 200 = 1256640$ lbs. raised 1 foot, and this divided by 33000 gives 38 H.P.

In the same way any other example of a like kind may be computed; but when the question has respect to the per centage of power obtained from an applied power such as water, the calculation is slightly more involved. To illustrate perhaps the most difficult form in which this question is likely to present itself in practice, we shall give an example of the mode of calculating the power from an experiment made by means of the friction-brake on one of Mr Whitelaw's water-mills of only $7\frac{1}{2}$ inches diameter.

The height of the fall was 10·13 feet, and the
Quantity of water expended in one minute 10·6 cubic feet.
Revolutions of the water-mill in one minute 778.
Weight kept suspended by the brake 10 oz = ·625 lb.

10 feet, the circumference of the circle which the point on the arm of the brake at which the weight was suspended, would describe if the brake were turned round on the spindle of the machine as a centre, or the length of the arm is $\frac{10}{3{\cdot}1416 \times 2}$ feet.

Here $10{\cdot}6 \times 62{\cdot}3 \times 10{\cdot}13 = 6689{\cdot}6494 =$ the power of the water, and $778 \times 10 \times {\cdot}625 = 4862{\cdot}5$. Therefore the power of the machine is expressed by $\frac{4862{\cdot}5}{6689{\cdot}6494} = {\cdot}727$, the power of the water being reckoned 1; that is, the water-mill in this experiment gave 72·7 per cent, of the whole power of the water expended in working it, which we may observe is rather a remarkable result from so small a model.

It must of course be understood, that in using the double lever brake, the sum of the weights must be taken as the weight P necessary to balance the power of the machine: the calculation is not however in any other way affected.

From these observations it will appear that the arithmetic of the brake is simple; and that its action offers perhaps the greatest amount of certainty which we can obtain of the working efficiency of any prime mover. Tredgold recognises its simplicity and accuracy as a test of the qualities of an engine, and recommends it to the notice of those who are desirous of having good engines. In France, it is in common use; and already we find the newer French treatises on practical mechanics, abounding in tables obtained by the brake of the power required to drive various kinds of machinery in their mills and factories. Our neighbours have not as yet the same means of obtaining results which we possess, but by making a more industrious use of their facilities, they are fast excelling us in exact knowledge of the applications of mechanical agents. It has been fashionable with our practical men to decry everything having the appearance of theory in their particular pursuits; but it must not be forgotten that theory is the perfection of art, and that art cannot be perfect while theory remains incomplete. Every person is therefore directly interested in the accumulation of data, the groundwork of all advancement both in abstract and applied knowledge, of which mechanics is only an important branch.

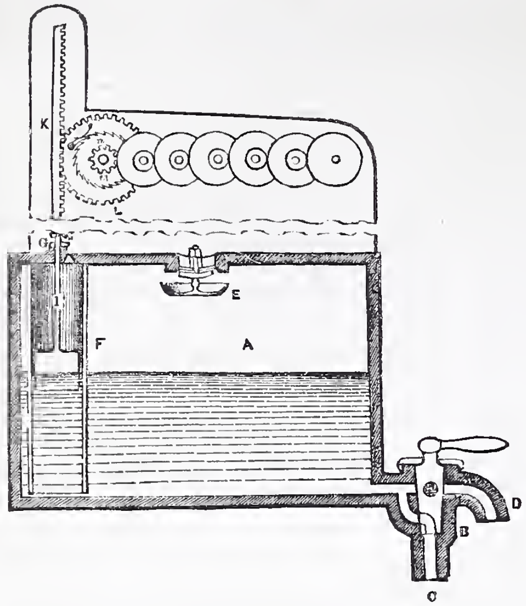
DESCRIPTION OF A NEW WATER METER.

By Mr. J. Maxton, Engineer, Leith.

The following description and drawing (on a large scale), of this form of water-meter, were lately submitted to the Royal Scottish Society of Arts. I believe it to be original, and to have some points of superiority over most contrivances of the kind which have fallen under my notice. The sketch annexed shows the meter in section.

A is a square cistern, B a two-way cock; C the induction pipe; D the eduction pipe; E an air valve with float attached; F is a small cylinder, the lower end of which is one-eighth of an inch clear of the bottom of the cistern, to allow the water to fill and

empty out of the cylinder. G is a stuffing-box, and H a float working easily in the cylinder; I a rod attached to the float,



which passes through the stuffing-box G. At the top end of the rod I, is a rack K, which works the spur-wheel L (which is loose on the spindle.) M is a ratchet-wheel fixed on the spindle along with the pinion *n;* this pinion works the rest of the wheels, the same as in a common gas meter. On the side of the spur wheel L, is a catch which is kept on the ratchet wheel by a spring as shown in the sketch.

In the position shown, the cock B is allowing the water to fill the cistern by the induction pipe, at the same time shutting the eduction by the upper hole in the cock. When the water rises in the small cylinder, it raises the float and rack, and works the wheels of the counting apparatus, and when the water rises to the top, it shuts the valve and prevents escape, the quantity contained in the cistern being registered by the indices in the act of filling. In drawing off the water for use, on turning the cock, it opens the eduction, and shuts the induction at the same time, and, from the nature of the ratchet wheel and catch, the indices are prevented from registering, when the cistern is being emptied.

Objection may be taken to this form of meter, on account of its not being adapted to afford a continuous supply of water. In other respects it is ingenious and simple, and obviously accurate within very narrow limits.

MEANS OF PREVENTING DAMP IN WALLS.

By C. L. Eastlake, Esq.

(*Slightly Abriged.*)

In buildings erected without due precautions, in humid situations, it is found that the damp rises through the masonry by capillary attraction. The external coatings of the walls are thus affected to a considerable height: not only paintings are destroyed, but the plastering itself becomes detached. In Venice, where the foundations of so many houses are partly immersed in water, it has been remarked that the plastering is frequently loose, even to the height of twenty feet: the presence of damp at a still greater height, in a less pronounced form, may therefore be inferred. It is probably owing to the action of moisture thus communicated, that paintings in the open air have decayed so generally in Venice; for the sea air, which is sometimes assigned as the cause of this decay, has had no such effect on external painted decorations in Genoa, the foundations of the houses being there dry.

In Italy, the use of pozzolana in mortar, and the warmth and dryness of the air in summer, tend to arrest or repel the progress of damp; so that its consequences, even in exposed situations, are less rapidly destructive than in northern climates. These correcting causes, insufficient as they sometimes prove, may account for the absence of any precautions in Italian and in ancient Roman buildings to check the ascent of moisture in walls. The ancients sometimes took effectual means to exclude damp *laterally* by means of double walls, but, except by placing charcoal or other dry materials under pavements and foundations, they seem to have taken no care to intercept the progress of moisture in a *vertical* direction. The method, recommended by Vitruvius, of excluding damp by double walls, was occasionally adopted in Roman edifices in this country; for example, in the Roman villa at Woodchester, in Gloucestershire, and in that of Mansfield-Woadhouse, in Nottinghamshire. These precautions may account for the comparative preservation of paintings on the internal surface of the walls of houses so constructed.

Modern architects on this side the Alps, compelled by the effects of a humid climate and soil, have gone to the root of the evil. M. Von Klenze, of Munich, having remarked the occasional ravages of damp on the external and even internal walls of many Italian buildings, and the consequent decay of the paintings executed upon them, adopted a remedy, which is now common in Munich. At the third course of bricks (the material usually employed in Munich) above the surface of the ground, the whole horizontal surface of the wall is covered with a thin sheet of lead, which is protected by a coat of pitch on each side; the building then proceeds as usual. The dry gravel-bed within the foundations is considered sufficient to protect the ground-floors; and the possible ascent of moisture by the walls is at all events guarded against by the sheet of lead coated with pitch. M. Hittorff, of Paris, being consulted as to the durability of lead so employed, was of opinion, from numerous instances of its use, though for different purposes, in ancient edifices and in ancient sculpture, that it may be considered sufficiently durable, when protected in the manner above described.

A layer of asphalte on the horizontal surface of the walls immediately above the surface of the ground, has been recommended by M. Polonceau as an effectual means of preventing the ascent of humidity in buildings. A writer in the 'Revue Générale de l'Architecture' for February, 1842, states that in 1839, he adopted Polonceau's precaution in a house of three stories on the Lac d'Enghien. "The foundation of the building is constantly in water, about 19½ inches below the level of the ground-floor. The entire horizontal surface of the external and internal walls was covered, at the level of the internal ground-floor, with a layer of Seyssel asphalte, less than half an inch thick, over which coarse sand was spread. No trace of damp has shown itself round the walls of the lower story which are for most part painted in oil of a gray-stone colour. It is well known that the least moisture produces round spots, darker or lighter, on walls so painted. Yet the pavement of the floor, resting on the soil itself, is only about 2½ inches above the external surface of the soil, and only 19½, at the utmost, above that of the sheet of water.

"The layer of asphalte having been broken and removed, for the purpose of inserting the sills of two doors, spots indicating the presence of damp have been since remarked at the base of the door-posts.

"The porter's lodge is built on a higher level, with similar materials, but, being less exposed to damp, the walls were not defended with asphalte: the foundations do not descend to the water-level, and the ground-floor is boarded: yet the lower parts of the walls are spotted with damp. This affords decisive evidence that the preservative in the first-mentioned case is the asphalte.

"I confess I was not without fears as to the compressibility of the asphalte, when softened by the great heats of summer, although I am inclined to believe that walls of 20 inches thick never attain the temperature of the atmosphere, especially at the base, on account of the proximity of the soil, and the alternation of temperature by day and night. I thought it, however, possible that the layer of asphalte might spread under the pressure of the walls and protrude beyond the external joint, but it has not protruded a millemetre, (about the 26th of an inch.)

"I had even supposed that the unctuous nature of the asphalte might, in case of an unequal settlement of the foundations, occasion a partial slip of the materials. To obviate this, rows of flints, as large as the fist, had been incrusted midway in the

thickness of the masonry, and parallel with the axis of each wall, forming a sort of key (*engrenage*) between the foundation and superstructure. The asphalte, it is to be remembered, entirely covered these flints.*

"Another house was built at the same period, on the same soil, at the distance of about 33 feet from the one above mentioned. The area of the ground-floor of this second house is 2 feet $1\frac{1}{2}$ inches above the level of the garden, and rests on sleeper-joists separated from the soil by an empty space of about 2 feet 7 inches in height, which is ventilated by numerous air-holes. Before this floor was laid, the horizontal surface of the foundation walls had been covered with a layer of Roman cement about an inch thick. Notwithstanding all these precautious the damp has ascended the walls as high as 3 feet and some inches above the level of the flooring.†

"Thus, of these two examples in the immediate neighbourhood of each other, and on the same soil, the building which was most exposed to the action of damp has been the best preserved from it, owing to the layer of asphalte.

"It should however be stated that the walls of the house where the asphalte was used, are constructed up to the basement-flooring, with a somewhat solid stone (*meulière*), and with a mortar composed of hydraulic lime, whilst those of the other house are built of lumps of gypsum, cemented with the same material even in the foundation. It is well known that constructions in stucco absorb moisture, even before saltpetre shows itself, much more easily than constructions in mortar. I have seen an instance where the damp has risen 4 or 5 feet in a few days in a slightly-built enclosure cemented with stucco, the base of the wall being in water.

"There is, therefore, every reason to conclude that the method tried and warranted by M. Polonceau is safe. It is even preferable to the mode last referred to on the ground of economy, since the layer of asphalte proposed by him is only 5 millemetres (less than a quarter of an inch) thick."

The same writer observes that "to prevent damp from penetrating the walls of ground-floors, it is usual to paint their perpendicular surfaces, to line them with wood-work, or with plates of metal. These methods prevent in some degree the evaporation of moisture in the apartments; but, far from hindering the ascent of humidity from the soil, they, on the contrary, promote it. Oil-paint, applied to the external surfaces of walls, is a certain means of rendering the rooms of the ground-floor uninhabitable. The damp, with which the base of the walls is saturated during winter, being no longer allowed to evaporate on the outside by the action of the sun and the warm dry air of summer, is driven inwards. If, again, wainscot or zinc linings, or coats of paint, be opposed to it internally, the damp, rotting or oxydizing such protections in its progress, may ascend to the first story, especially if the walls be cemented with stucco. I have seen examples in the country of walls thus treated, in which the damp ascended every winter to the height of about 27 inches above the level of the ground. A coating of zinc, 1 metre ($39\frac{1}{3}$ inches) in height, was, in one case, applied to remedy the evil; the following year the damp rose to 30 centimetres (about 13 inches) above the zinc: lining was raised 50 centimetres ($19\frac{1}{2}$ inches) higher, and the following spring the moisture had passed even this new protection by 20 or 30 centimetres. These facts and observations warrant the conclusion that the only means of preventing moisture from penetrating the walls of the ground-floor consists in interposing between two courses of masonry, and at the level of the internal ground, an elastic and but moderately compressible substance, which shall be impermeable, incorruptible, and insoluble,—such as bitumen properly prepared, lead, tin, &c.*

"As before observed, oil-paint on the outside of houses in almost every case is rather injurious (as regards the point in question) than otherwise. It does not expel the damp from within, on the contrary it drives it back. It does not even preserve stucco coatings, for, after the application of the paint a sort of chemical decomposition takes place in them. On every part exposed to the rain, the wet, lodging in the numerous minute fissures which take place in a few years in the pellicle of paint, dissolves the plaster, producing channels which rapidly increase, and give the surface a worm-eaten appearance. To remedy this evil it would be necessary to re-paint the walls every two or three years, which would be a serious expense.

"The application of paint on flimsy surfaces of stucco has undoubtedly a specious appearance, but nothing can be adduced in favour of its employment on façades of stone. The only coating and preservative which should be allowed on the surface of stone walls, is that which, by its unalterable transparency, is calculated to preserve the grain, the colour, and the *mat*, or absence of shine, in the stone. Of all known methods, encaustic-painting appears to me the only one calculated to accomplish these objects, when it shall have undergone, in its preparation and application, all the improvements of which it is susceptible. But in order that the employment of a hydrofuge of whatever kind on the perpendicular surfaces of walls be effectual, it is indispensable in the first instance to prevent the moisture of the soil from ascending through the walls, and then to devise means of drying the masonry completely before the application of the hydrofuge on the vertical surfaces."—(*H. Janiard.*)

In Italy, paintings on ceilings and on the upper parts of walls have been damaged, and in some cases obliterated, by the moisture penetrating from above; but in a well-constructed edifice, duly inspected from time to time, the danger from this cause is so remote that it can hardly be necessary to call attention to it. The infiltration of water from pipes was, however, the means of destroying a painted ceiling in the Louvre at no distant period. The possibility of such accidents might suggest precautions; for example, coatings of asphalte in the upper portions of walls, and over ornamented ceilings. The injurious effect of flues behind paintings is an evil of an opposite kind; the best means of intercepting the heat would be to leave an empty space (with holes opeuing into the room to ensure a circulation of air) between the flue and the back of the bricks or tiles on which the painting is executed.

It remains to consider the precautions which may be more immediately necessary for the preservation of paintings from damp behind them, whether such paintings are executed on the surface of the wall itself, or whether they are applied to it subsequently to their completion.

First, with regard to fresco:—The appearance of damp and of saltpetre may be prevented either by a space between the solid masonry and the surface (composed of thin bricks or tiles), which is to receive the mortar and intonaco for the painting; or by a hydrofuge composition or coating impervious to damp. In the latter case it may still be desirable to add a surface of tiles upon or without the hydrofuge, in order to form a proper ground for the mortar, and to assist in absorbing and retaining the moisture, which is freely applied to the surface before and during the execution of the fresco. For, the less absorbent or retentive of moisture the ground is, the quicker the fresco will dry, and consequently the greater will be the inconvenience of the execution. Where the mortar and intonaco are thinly spread on a surface of stone, as sometimes happens, very little absorption can take place; but the difficulty which such a case might present to the painter need not be encountered unnecessarily. It may however be assumed, that a coat of mortar, of the usual

* An experiment of this kind was made in building a theatre of anatomy on the site of the Cemetery "De Clamart," in Paris. The asphalte was applied in too liquid a state, and flowed out at the joints, in consequence of the pressure of the mass of wall above it. In consequence of this partial failure, objection was made to this mode of operating entirely; the cause was however met by M. Polonceau, in his anwer, who explains that the asphalte employed by him is not apt to escape, even in summer, and under the greatest pressure, and that it is nevertheless elastic at a temperature of four or five degrees below zero. He further explains that it differs from the asphalte sometimes employed for pavements, inasmuch as it contains no lime; and also adds, that one-fourth of an inch is quite thick enough for the layer, and that coarse dry sand should be well and evenly spread over it.

† A similar instance of the inefficacy of cement for the purpose in question is recorded in the 'Transactions of the Institute of the British Architects,' vol. i. p. 59.

* The efficacy of this contrivance cannot be doubted, and it may be considered an indispensable *first* precaution against damp; but it need not supersede the application of suitable protections on the perpendicular surfaces of walls. It must be obvious that, provided there be no damp to escape from within the body of the wall, there can be no danger in rendering the exterior surface impervious to it. On the western coast of England the sides of houses are often lined with slates; and some such defence (in addition to that above recommended) would often be necessary in exposed situations.—*Eastlake.* A mode which has been found effectual in houses built on Blythswood Hill, (Glasgow,) is to lay a course of Arbroath flag enveloped in lead on the horizontal surface of the walls immediately above the surface of the ground.—Ed.

thickness, spread on any surface to which it will firmly adhere, would always constitute a sufficiently absorbent ground, as frescos can be executed without inconvenience on lath.

The practice of applying the mortar and intonaco on a pitched ground, without tiles, is said to be common in Lombardy. The dome of S. Celso, in Milan, painted by Appiani, was thus prepared. The hydrofuge is composed of pitch and sand thrown roughly on the solid wall; to this the superadded mortar adheres so firmly, that in breaking walls thus faced, a fracture never takes place at the junction of the two. But supposing thin bricks or tiles to be employed, they might be encrusted or embedded in a similar hydrofuge ground, which would effectually exclude all damp and saltpetre from the solid wall. The surface of the tiles would require to be roughened on both sides, and this could be best done before the clay is baked, in order to ensure the firm adherence of the softer substances.*

Saltpetre, it may be objected, might still come to the surface, even from one course of bricks or tiles. The general precaution taken at Munich is to use bricks that have been well burned, at the same time and place, of the same clay, and in an equal degree. The mouldy efflorescence which sometimes shows itself may be removed by a wet sponge. It remains to observe that at Munich no hydrofuge is applied behind the superficial course of bricks, or behind the mortar; such precautions are considered superfluous; and, provided the progress of damp in a vertical direction be entirely intercepted, they may perhaps be considered unnecessary in any case.

Some distinguished French chemists have of late years directed their attention to the means of excluding damp from the internal surface of walls not protected above the foundation in the mode before described. The following is a translation of some observations on the subject by MM. D'Arcet and Thénard. The experiments made by them were begun in 1813, when M. Gros undertook to paint the cupola of the church of St Geneviève (then called the Pantheon).

"The surface of the cupola had been previously prepared like a primed cloth: after the stone had received a coat of strong size, a ground of white lead and drying oil had been superadded. Fearing that this priming was not sufficiently firm, M. Gros came to consult us. We did not hesitate to say that it was far from safe. The moisture might in time, we observed, act on the size, and a painting executed on such a ground would consequently change. We soon came to the conclusion that it would be necessary first to saturate the stone as deeply as possible with an unctuous substance, liquefied by heat, and which, solidifying as it cooled, would stop up the pores of the stone. We were strengthened in this view by the authority of the ancients, who sometimes passed melted wax over the surface of walls which they intended to paint, and we were induced to try a coating of wax and linseed oil, rendered drying by litharge. After some experiments on stones, similar to those of the cupola, we were led to prefer a composition consisting of one part wax and three parts of oil boiled with one-tenth of its weight of litharge. The absorption took place readily by means of heat, and the liquid penetrated the stone to the depth of from a quarter to half an inch. The composition, as it cooled, acquired solidity, and in six weeks or two months became hard.

"Having made these experiments, we proposed to adopt the same means on the cupola, and the operation was to be conducted as follows:—The surface was first to be scraped, so as to entirely remove the preparation of paint and size, and lay the wall bare; then, by means of a portable furnace, the whole superficies was to be heated, portion by portion (about a square yard at a time), and the mastic† or composition was to be applied, at a temperature of 100 degrees, with large brushes. The first application being absorbed, a second was to be added, and so on until the stone should cease to absorb. To promote the absorption, the stone was to be warmed repeatedly, according to its porousness. In every case the heat ought to be as great as possible, but not so great as to carbonize the oil. At length the stone being saturated to a certain depth with the mastic, and the surface being smooth and dry, it was to receive a coat of white lead mixed with oil, and on this preparation the painting was to be executed.

"Our plan was adopted and put in execution; and thus M. Gros was enabled to produce a new masterwork, which could undergo no change except that which light and air might occasion. Drops of water, like dew, which covered the whole surface of the cupola every morning, at first alarmed the artist. We knew, however, that there was nothing to fear from this; (it could only have been a condensation of moisture from the interior), the drops appeared and disappeared without the slightest bad consequence, and a trial of fifteen years has now dissipated all apprehension."

For ordinary purposes resin might be substituted for wax: the ingredients then are, one part of lithargirized oil to two or three parts of resin. This composition has been employed with effect, with the aid of heat, to protect internal walls from damp. A remarkable instance of its successful application, related in the same memoir, is here added.

"Two rooms on the basement story at the Sorbonne happen to be several feet lower, on the east and south sides, than the ground-level of the neighbouring houses. The walls of the two rooms on those sides are impregnated with saltpetre. Some years since it was thought advisable to coat them with stucco, in the hope of driving the saltpetre to the outside; but it penetrated the stucco, and re-appeared on its surface, producing so much damp that the plaster began to be decomposed, and the place became uninhabitable even in summer. Our method was tried in these rooms in the following manner:—A mastic was composed, consisting of one part linseed oil, boiled with one-tenth of its weight of litharge, and two parts of resin. The latter was melted in the lithargirized oil in a cast-iron vessel, the fire being duly regulated. The substances tumified considerably at first, but the fusion once completed, this effect ceased: the composition was suffered to cool, to be again heated for use. The tumefaction which takes place requires that the resin should be dissolved in the oil by degrees, otherwise it will overflow. The walls being very damp, it was necessary to dry them by means of a portable furnace. That which we made use of was about 1 foot 8 inches wide by 1 foot 4 inches high, so that we could dry a surface of 6 or 7 square feet at a time. The furnace was provided with two rings on the upper anterior corners, serving to hang it on a horizontal iron rod, about 5 feet 4 inches long. The ends of this rod rested in racks in the edges of two perpendicular boards, about five feet asunder, bound together by two braces, one above and one below. These boards, which, with their connecting braces, formed a portable framework, were nearly as high as the rooms (about 10 feet 8 inches): they were placed at a due distance from the wall. The furnace* was provided at the back with two handles, by means of which it was easily shifted on the iron rod from which it was suspended.

"From this description, the details of the operation itself may be easily conceived. The apparatus was stationed opposite a given portion of the wall till that portion had received the mastic. The composition, thus successively applied, formed eight horizontal bands, each as high as the furnace, and extending in length to the extent of the wall. The workmen began by drying the plaster thoroughly.† It was afterwards again heated, portion by portion, to enable the mastic to penetrate it, as in the case before described. The upper part of the wall was completed first. When a given portion of the wall was sufficiently heated, the furnace was pushed along the rod from which it hung to the next portion in the same line; and while the second portion was being heated, the composition was applied to the first. But if the wall did not absorb sufficiently well, the furnace was re-shifted to its first position, and placed at the requisite distance from the surface. Upon this, air-bubbles were rapidly disengaged, and the absorption took place in a very short time. The mastic was applied without intermission till the plaster ceased to absorb. Five thick layers were absorbed; the sixth was only partially so, and formed a slight glaze on the surface, which after a time became very hard. The upper band or portion having been covered, the rod and furnace were lowered

* The tiles and flues found in the remains of the Roman villa at Woodchester were thus toothed. Lysons, ib. Vitruvius (l 7. c. 4) recommends giving tiles a coat of lime and water before the application of the mortar, to ensure the adherence of the latter.

† The word "mastic", is sometimes used both by French and English writers as a general term for cements and coatings.

* The furnace, heater, or cauterium, was made like a common barred grate, except that it was furnished with a half-closed lid to protect the ceiling from the heat. A similar furnace may be applied by means of a pole fastened to the back, instead of being suspended from a rod.

† The authors state that 120° are about the maximum of heat which plaster will bear; at 145° it became decomposed.

about 1 foot 8 inches, and the remainder of the wall, in successive bands, was treated in like manner. The cost, without reckoning time and labour, was 16 sous the square metre (about 7d. the square yard) : it would be less on stone, because there would be less absorption, and therefore less consumption of the ingredients.

"The stucco became hard in a short time : it is now difficult to make an impression on it with the nail of the finger. In two spots it had been too much heated : these portions were replastered. Where saltpetre is very abundant, the composition penetrates with difficulty, and is apt to fall off in scales : in this case also it would be necessary to renew the stucco. The operation always succeeds perfectly on new and dry stucco.

"Another, and perhaps the best mode, where walls are much impregnated with saltpetre, is to remove the plaster, to reface the surface of the stone with the peck, to stop the joints well, and then cover the whole with the composition : the surface may then be cloth-papered."

A similar mode of rendering pavements dry is also described ; and the authors recommend saturating stucco on ceilings with wax and lithargirized oil, as a preparation for oil-painting. The composition, it is observed, penetrates so deeply into stucco, that no damp from the body of the wall or roof can decompose it ; it becomes so hard at last that broken stone-work has been made good by adapting the stucco to the forms or mouldings first, and then saturating it. The writers proceed to state, that a ceiling in the Salles des Antiques, in the Louvre, painted by Barthélemy in 1801, was destroyed in 1820 by the infiltration of water from the room above : they observe that, had the stucco of this ceiling been prepared in the mode before described, the painting would still have existed. "The above methods," they add, "may be employed to expel damp from ground-floors, and from cells of prisons ; to make cisterns and reservoirs water-tight ; to render vases of plaster fit to contain fluids ; and, among various other uses, to preserve corn for any length of time in subterraneous chambers."

In preparing a wall for encaustic painting, the surface of the stone is first heated in the mode above described, and is then saturated as deeply as possible with wax, dissolved either in the volatile oil of wax, in that of lavender, or in highly rectified spirits of turpentine.

To recapitulate : should it be thought desirable to prevent the possible egress of damp or of saline particles from a brick wall upon which a fresco is to be painted, the surface of the bricks may be well covered with a hydrofuge. The composition might be melted in the mode above described, or it might be applied as a solid coat ; in the latter case its surface should be so roughened as to afford a sufficient hold for mortar ; if, again, the mortar alone should be thought not sufficiently absorbent, tiles, which might be made to adhere perfectly to the hydrofuge, might be interposed between it and the ground on which the fresco is to be executed.

On a surface of stone, for example, on the walls of Westminster Hall, even assuming that the ashlar in its present state affords a sufficient tooth for mortar, the little absorption that could take place might possibly render the execution of fresco inconvenient. This point could be easily determined by making experiments on stone of a similar quality. That used for the new buildings closely resembles the ashlar of Westminster Hall. Should such a material prove unfit, it would be necessary to fasten tiles against the wall ; and this it appears could be effectually done by various cements : thus prepared, the surface would be sufficiently absorbent.

In the preparation of an ashlar wall for encaustic or oil painting, no difficulty presents itself. The surface of the stone should be heated and saturated as deeply as possible with a composition similar to those above described, the joints of the stones being well stopped. The cement sometimes used for this purpose in Paris is the "cément de Dihl," composed of the outer scales of fire-bricks pounded and mixed with oil. As the cément de Dihl, employed to stop the joints, cannot absorb the mastic during the process above described in the same manner as the stone itself absorbs it, the surface of the painting sometimes shows the lines of the joints, producing a partial change of tint. This might be obviated by merely stopping the joints with stucco, and relying on the mastic to give it a hydrofuge quality, together with the stone, by which means the surface would be homogeneous, while the operation would, at the same time, impart sufficient hardness to the stucco. The firm adhesion of various hydrofuge cements to mortar or tiles may render such cements preferable in every case where it is desirable to intercept damp behind paintings executed on walls. Some of them are here enumerated. The mixture of oil and lime, recommended by Vitruvius (l. 7, c. 4), as a cement well calculated to exclude damp from pavements, has been often introduced as a novelty by the moderns. Hamelin's mastic is said to be thus composed ("Gwilt's Encyclopædia of Architecture," p. 509.) The mastic de Loriot, said by the last-named authority to be the same, is, according to Biston ("Manuel du Chaufournier," Paris, 1828), merely a compound of lime and pounded tiles or flints, without oil. Various compounds are used by the Italians ; such as lime slaked in bullock's blood, the whole being mixed with pounded tiles and iron filings ; lime mixed with eggs, &c. The mastic de Vauban is composed of finely pounded tiles, lime, and linseed oil (Biston, *ib.*). The mastic de Tunis, which is employed to line the cisterns in that kingdom, and is said to be the same as that used in the ancient cisterns of Carthage, is composed of wood-ashes, lime, and fine sand ; its peculiar tenacity is the result of constant beating for several days, while oil and water are thrown upon the ingredients in small quantities alternately. The mastic à la litharge (see "Chimie de Thénard," v. 2), and the mastic de Corbel, are also composed partly of oil, (*ib.*) A cement composed of lime, linseed oil, white lead, and sand, is recommended by Merimée ("De la Peinture à l'Huile," p. 247). Many of these adhere firmly to the smoothest surfaces ; the recently patented "stucco paint cement" of Messrs Johns and Co. adheres to glass.

DICK'S ECCENTRIC ANTI-FRICTION PRESS.

The machines, called the Anti-friction Press, which were exposed in the American part of the Great Exhibition of 1851, are allowed to be one of the most striking improvements in mechanics. This press is the invention of D. Dick, Esq., of Pennsylvania, U.S., and is now extensively employed in the United States, where it was patented by Mr. Dick in 1848. The English patent was dated January 1, 1850, and now belongs to Mr. J. Stuart Gwynne, Agar Street, Strand, to whom applications for machines, or for licences to manufacture them, may be addressed. Where great power is required in small compass, this press has many advantages ; it almost annihilates friction, economizes time and labour, and is, indeed, generally admitted to be, for most purposes, superior to the hydrostatic and other presses.

It often happens that machines exhibit admirable combinations, which promise to work remarkably well, but, when brought to the test of experiment, greatly disappoint the expectations which were formed of them, in consequence of such an amount of friction as could not easily be foreseen, and which greatly diminishes their power. It is not so with the Anti-friction Press, in which the amount of primitive resistance from this source is so small, that its increase is scarcely appreciable, even when the press is employed to produce effects which require a very great degree of power.

This will be at once understood by inspecting the annexed engravings, where the reader will observe, that in place of pivots, producing an amount of friction proportional to their diameters, there are only angles or corners in contact, the friction of which may be considered as nothing. And then, a great superiority in this arrangement over all other machines of the same kind, consists in the fact, that lateral pressure is avoided, and in place of friction by eccentrics, which is always enormous, and which uniformly increases with the effect required, there are here only simple motions and direct action, in which the entire power is developed. Indeed, mathematically speaking, the machine has no friction, and, practically, less than any other combination or arrangement for the multiplication of power by mechanical means.

M. Colin, of Paris, who was in London at the opening of the Exhibition, states, that when he saw these presses on the first day of their arrival, after examining the surfaces of the cylinders, and those of the presses, which were polished with coarse emery-paper, and likewise rubbed across, so as to form an in-

finite number of small teeth to prevent the slipping or sliding of the surfaces on each other, he at first believed that, after having operated a certain time, the surfaces would soon become perfectly polished, and thus the rotation produced by their mutual contact be performed with less power. In this anticipation he found himself quite deceived; for even on the last day of the Exhibition, though the surfaces were very much polished in consequence of frequent experiments made during the six months that the Exhibition lasted, he found there was not the least sliding, even after experiments which, in point of fact, were pushed perhaps a little further than the strength of the machines warranted.

To aid in understanding the accompanying designs and diagrams of this arrangement, we shall give a description of the principal parts of their functions; and as the inventor has applied the machine to various purposes, we shall begin with that particular form which is used for piercing, cutting, or stamping metals.

ANTI-FRICTION PRESS FOR CUTTING AND PIERCING METALS.

Figs. 1, 2, and 3, represent the machine as applied to these purposes. The frame, properly speaking, is composed of two parallel rods or supports of cast-metal, joined below by two cross bars screwed firm, and above by the cast-metal beam, A,

Fig. 2.

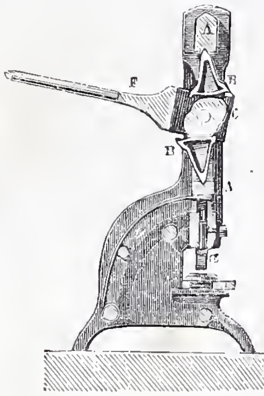


Fig. 1.

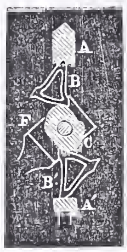
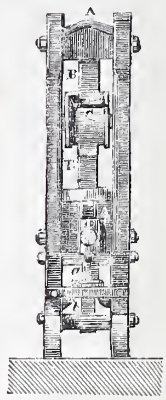


Fig. 3.



fixed in the same manner by screws. And as this part of the arrangement is subjected to considerable force from below upwards, the beam, A, to diminish the stress on the screws, is inserted a little into the blocks on each side. These blocks or supporting-rods are furnished with vertical grooves on their inner sides, in which the pivots of the lever, F, which terminates by the eccentric, C, have a circular and vertical motion, and in which slides also the block or stand, A′, for supporting

Fig. 4.

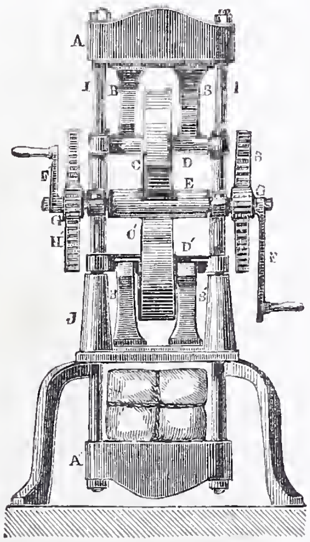


Fig. 6.

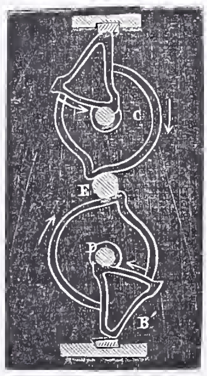
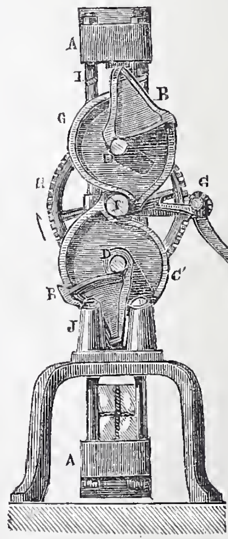


Fig. 5.



the cutting instrument. The latter is always pushed from below upward by the spring, *b*, attached to one of the inferior cross bars.

The cast-metal sectors, B and B′, terminating in arcs of a circle, are moveable at their angular points; the former, from above, under the beam, A; the latter, below, over the tool-stand, A..

The operation of this machine is easily understood from the diagram, fig. 1. The first thing to be done is to cause the tool-supporter, A′, to descend, the cross-beam being fixed.

This is accomplished by pulling the lever, F, from the position indicated in fig. 2 to that which is shown in fig. 1; for after this movement, the eccentric, C, which in fig. 2 presented its smallest diameter between the arcs of the sectors, B and B′, will present its greatest diameter, as in the diagram, fig. 1, and this has the effect of causing the tool-holder, A′, to descend. It is worthy of remark, that this movement is accomplished almost without friction, for the eccentric, C, is simply made to work on the arcs of a circle in the sectors, B and B′, which have only a slight friction at their angle in passing from the position in fig. 2 to that in fig. 1.

M. Colin operated with this machine a great many times, which was done with very little effort, as one may judge from the figures—these being drawn to a scale of one-twentieth; and he cut with it pieces of iron, of nearly half an inch square in section, without feeling the least resistance. The exact force to be applied might be theoretically calculated from the length of the levers, neglecting entirely that expended on friction, which is almost nothing, and which is generally so considerable in other machines, both eccentric and otherwise, employed for the same purposes.

ANTI-FRICTION PRESS FOR COMPRESSING CAOUTCHOUC AND OTHER SUBSTANCES.

In the same gallery of the exhibition was another machine of the same kind as the preceding, and perhaps still more ingeniously combined, though resting on precisely the same principle—we mean the anti-friction press for compressing a variety of substances, such as caoutchouc, threads, bales of cotton, &c. This machine is represented in figs. 4, 5, and 6, on a scale of one-twentieth the size.

M. Colin was able to reduce with this machine to less than half its thickness a block of caouthouc, 6 inches in diameter and 8 inches in height.

The base of this compressing machine is a support or stand of cast-iron, resting on four feet, and on this are supported the conical sockets or barrels, J, in which slide the four vertical rods, I, uniting the upper beam, A, of the press with the inferior bed-plate, A′.

Between the two rods on each side, are carried supports with cushions for the pivots of the arbor, E, which bears at its extremities the wheels, H, moved by the axes or journals of the pinions, G. And, as the centres of the eccentric wheels, C and C′, which are in contact at their circumference with the surface of the arbor, E, do not keep always the same distance from this arbor, their pivots are adjusted in vertical slots to keep them suspended in their places, but without turning.

By means of the handle or lever, F, mounted on the arbor of the pinions, G, the arbor, E, is made to turn, and this by its contact with the exterior surface of the eccentrics, C, C′, causes them to move so that their axes, D, D′, separate further from each other, and, consequently, as these axes, which do not turn, are in contact with those of the sectors B and B′, they communicate a small revolutonary movement to the latter.

On examining figs. 5 and 6, it will be seen that the frame of the machine, formed of the lower vertical rods, I, and of the beams, A and A′, rests entirely, by the axes, D, D′, on the angles of the sectors, B, B′.

Thus, when the arbor, E, is moved in the manner indicated by the arrow, (fig. 5,) the eccentric wheels are made to turn, and these having, in a state of rest, their shortest radii directed from this axis, as shown in the figure, the distance of the centres of these eccentric wheels is, as we have said, increased by the movement, so that we find them, at the end of their course, in the position represented in the diagram, (fig. 6.) This extension of distance may be easily verified by simply comparing, in figs. 5 and 6, the distance of the plates on which the sectors, B, B′, turn.

Now, as the plate which is connected with the inferior sectors, B′, rests on the fixed support of the machine, it is evident that that which is connected with the two superior sectors, B, must rise, and that it must drag up with it the inferior plate, A′, to which it is attached by the vertical rods, I.

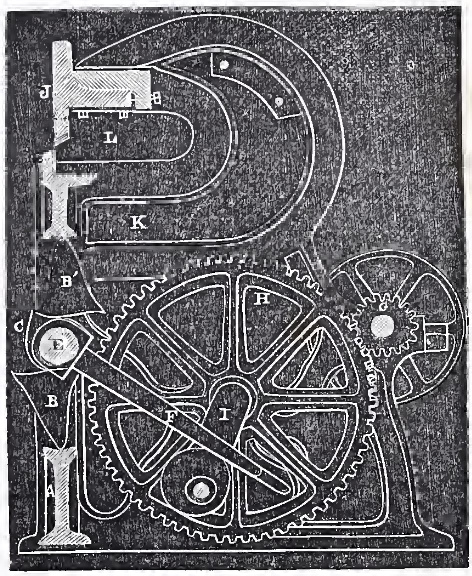
The object to be pressed is placed between the bed-plate, A, and the lower surface or plattin of the supporting-table, which, as shown in figs. 4 and 5, is pressed equally, above by the sectors, B′, and below by the object submitted to the action of the machine.

It may be remarked that, by this arrangement, the strength of the table is of little importance, inasmuch as the forces exerted upon it from above and below are equal.

ANTI-FRICTION PLATE SHEAR.

Among the different applications of the Anti-friction Press, there was yet another at the Great Exhibition—a shear for clipping or cutting metals, possessed of great power, and which is represented in the annexed sketch, (fig. 7.)

Fig. 7.



K is the side frame; A, the fixed support on which turns the angle or centre of the sector, B, which works on the lower part of the moveable eccentric, C, round the centre, E. On the upper part of the same eccentric operates the second sector, B′, which is moved in a verical direction by a quantity equal to the difference between the radii of the eccentric.

The piece, A′, which is pivoted at one of its extremities, rises, bearing on the angle or pivot of the sector, B′. On this moveable piece, as well as on the fixture above, J, are mounted sharp steel edges, as in ordinary shears. The axis of the toothed pinion, G, bears a cast-iron winch, which receives the impulse communicated by the mover to transmit it to the wheel, H, fixed at the extremity of the bent arbor, I, which operates as a lever, and, in turning, raises the long lever, F. The latter falls again by its own weight, resting on the button or bend of the arbor, I.

From this it will be easily perceived, that if a plate of iron be placed in the empty space, L, the lever, F, being at first in the position represented in the annexed cut, this plate must be cut by the shears on turning the handle, I, which raises the lever, F, and, consequently, causes the eccentric to turn a little; for this eccentric moves upward the lower blade of the shear, fixed on the moveable piece, A′, by operating on the sectors, B and B′, while the blade mounted on the fixed beam, J, remains motionless. The blades are three feet long, and sheets of any length may be cut by them in any direction, if not over three feet wide.

We are convinced that eccentric and anti-friction machines, on this principle, cannot fail to become extensively used in cutting and pressing operations, in which a high power is required. They admit of infinite applications, and their construction is simple and inexpensive.

NATURAL PHILOSOPHY AND CHEMISTRY.

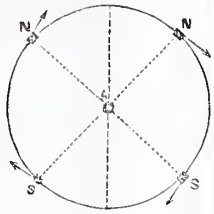
CHAPTER XXIII.

ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART II.—ELECTRO-MAGNETISM.

21. IT has been already stated that the electric force does not act in straight lines between the magnet and conducting wire, but tangentially, and in a plane perpendicular to the direction of the current: for instance, if this page be laid flat upon a table, and if in fig. 3 described upon it, a pin be stuck perpendicularly in the black spot marked A, the pin may be taken to represent a conducting wire in which a current is moving from head to point, or downward; in such case, the adjacent pole of a magnet N, resting upon the page, and pointing towards the pin, will move in that plane in the direction of the arrows, which are tangents to a circle* of which the pin is the axis; but if the other pole S, be substituted while the current flows in the same direction, the movement will be reversed, or be from right to left; and if the current be now sent from the point of the pin to its head, those poles which before moved in the direction of the arrows, will now move in the contrary direction.

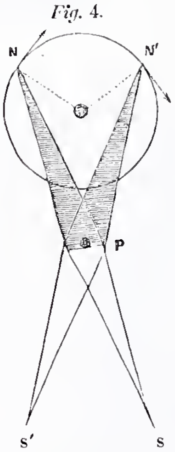
Fig. 3.



22. If this page be now set upright, or perpendicular to the table, the pin and current will be horizontal, and the plane of rotation will then be vertical; and if the current move from the head of the pin to its point, the arrows in fig. 3 will still exhibit the course of rotation, and the reversal of the current will cause a contrary course.

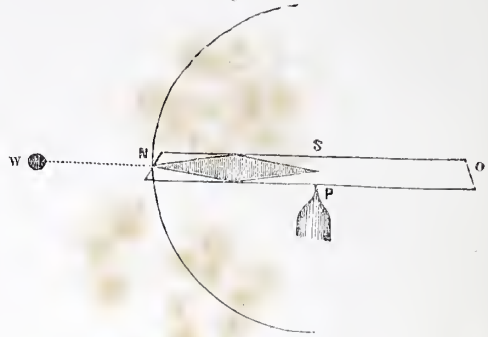
23. On this principle may be explained the movements first observed by Oersted; for if a magnetic needle, having facility of motion round its centre, be influenced by a current flowing parallel to it, its poles will become subject to an equal but contrary impulse, by reason of which the needle will assume a position across the current and at right angles to it, if the terrestrial polarity be neutralized. If the current be vertical, and be moving downward through a wire, of which S, fig. 4, is a section, the pole N, of the horizontal needle moving on a central pivot P, if placed on the left of the wire, will move towards it with a tangential tendency as indicated by the arrow; but if the current continue in the same direction, while the magnet is placed on its right, as at N′, S′, the pole N will move *from* the current with a similar tangential tendency, modified of course by the restraining effect of a fixed axis. In this way, there is an appearance of attraction in one case, and of repulsion in the other.

Fig. 4.



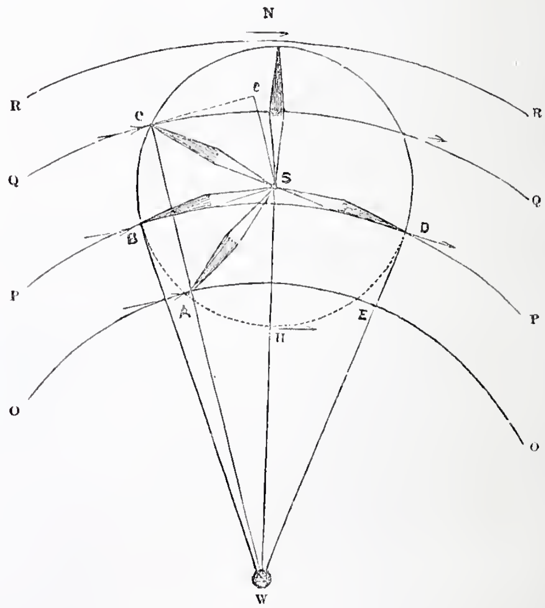
24. For the sake of simplification, we shall confine ourselves in the first instance, to the action of but one pole of a magnet—say the north pole—placed at different distances from a vertical wire of indefinite length, through which a current is descending, and we shall first take the case of a descending vertical current W (fig. 5.), external to a circle of which the magnet is a radius. The annexed figure will exemplify the influence of this current upon the north pole of the needle under such circumstances. In this figure, the needle, N S, may be supposed to be placed at length upon a narrow brass plate, N O, extended beyond the south pole of

Fig. 5.



the needle sufficiently to counterbalance it when the plate rests upon a pivot P, immediately under the south pole S, which is thus exactly above the centre of motion. It will be apparent that in such a position of the south pole, the action of a current upon that pole will not be such as to affect the movements of the bar, which will be influenced solely by the action of the current W, upon the north pole N, which is adjacent to it.

Fig. 6.



25. In fig. 6, let the spot, W, represent a section of the conducting vertical line down which the current is passing, and A, B, C, D, E, a horizontal circle, in which the needle, N S, revolves, S being the centre of motion. It will be at once perceived, that in whatever position the needle may be placed, the tangential force will act upon its north pole in the direction of a line which forms a right angle with another line, drawn from the conducting wire to the north pole of the needle, and which is consequently a tangent to one of the great circles, O, P, Q, R, of which W is the centre, and the lines drawn from W to the north pole of the needle are radii—the arrows denote the direction of this force; for instance, if the needle be at C, the tangential force has the direction of C c, perpendicular to C W, and at D it has the direction of S D, perpendicular to D W. At B, the force which tends to produce rotation of the needle round S, is re-

* The reader is requested to bear in mind, that all the figures in this treatise, in which it is of importance to note the direction of the magnetic movements in relation to the electric current, are so constructed that the part of each figure nearest the top of the page is supposed to be *north* with reference to the other parts of the figure.

duced to nothing, being directed to the exact centre of motion at S; but at C, or at any other position of the pole in the circumference, between B and a point in the circle at the right side of the line W N, equidistant from H, in the segment of the circle adjacent to W, the force producing rotation will be proportional to the cosine of the angle formed between the line connecting the north pole of the needle with W, and the needle itself. In other words, it will be proportional to a line drawn from the centre of motion S, parallel to the line connecting the north pole with W, until it meets another line which is a continuation of the tangent to the circle of which the connecting line is a radius, and to which that tangential line is perpendicular. This parallel line which in the figure is represented by S *c*, when the pole is at C, may be considered in the light of a lever acting upon the needle at C, and drawing it towards N, and as the length of the lever, or—which is the same thing—of the line connecting the pole with the conducting wire, increases as the pole moves from the neutral point B, until it reaches N; and after passing N, diminishes until it reaches the other neutral point D, so does the tangential force upon the pole of the needle increase or diminish in a like proportion.

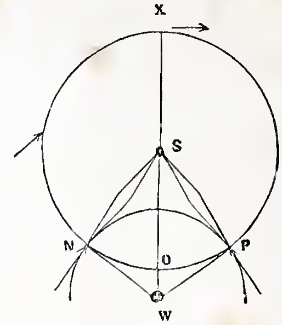
26. When the pole reaches the neutral point D, it is then said to be in equilibrium, and that equilibrium is stable; for if the pole be forced onward to E, the lever will then be within the smaller segment of the circle, which it will be perceived is divided into unequal portions by the two neutral points, and its tendency will be to drive the pole of the needle backward, or towards the neutral point D; the needle will therefore again fix itself at the neutral point, after a few oscillations.

27. If the needle be advanced farther in the direction of the point H, the force of the lever impelling it in a contrary direction, will increase until that point is attained, at which the needle points directly towards the conducting wire; but if it be carried beyond that point, the contrary force diminishes gradually, until the neutral point on the left side is reached, where the needle is again in equilibrium; but, in this case, an unstable equilibrium; for, if the needle be made to oscillate ever so little, its tendency will be to pass the neutral point, and move onward with increasing rotatory force until it reaches N, and with diminishing rotatory force afterwards, until the position of stable equilibrium is once more attained at D.

28. It has been already observed that the needle is urged in opposite directions in different parts of the circle; that, in the northern or remote portion, its tendency is onward from west to north, and north to east; but in the adjacent or southern portion, the tendency is from west to south, and south to east; but inasmuch as at the neutral point on the left, the tangential force is in a direct line with the needle itself, which is therefore at right angles to the line connecting its pole with the conducting wire, this force, so acting, gives the needle a forward impulse, exceeding the contrary impulse to which the needle would be subject, if its pole lay on the southern side of the neutral point, and in consequence it is carried round the *larger* arc, in place of the *smaller*, in its endeavour to reach its position of stable equilibrium;—thus, that preference for the *circuitous*, in place of the *nearer* path to its destination, which appeared so marvellous and inexplicable to the earlier observers, must now appear, to the attentive reader, only a natural consequence of the tangential direction in which the electro-magnetic influence operates.

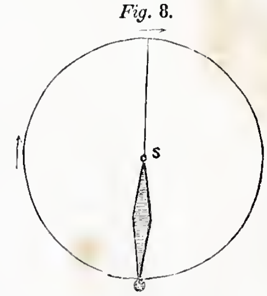
29. When the conducting wire is placed very near the circle round which the pole of the needle moves, the disproportion between the unequal portions of the circle is considerably augmented, and becomes still greater, the nearer the wire is approached to the circle; thus, in figure 7, the arc N, O, P, is extremely small compared with the larger arc N, X, P; but if the needle be placed at the least possible distance from the line connecting the centre of motion with the conducting wire, and upon the left side, in place of passing over the diminished arc to attain the point, P, of stable equilibrium, it will instantly recede from that point and move in the opposite direction, as if repelled, until, by the circuitous route, it reaches the point of permanent neutrality.

Fig. 7.



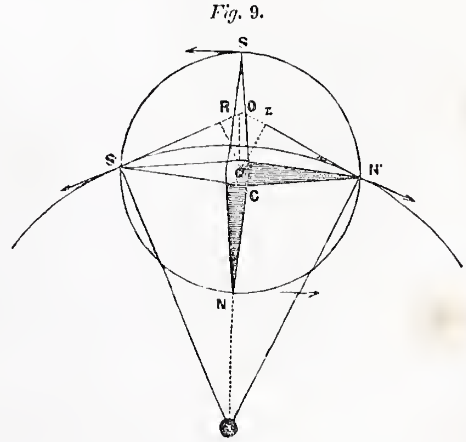
30. If we suppose the conducting wire to pass through the circumference itself, in such case the arc, which in the former case separated the two neutral points, is reduced to nothing; and therefore, if the needle be placed on the left of the wire, but nearly in contact with it, as in fig. 8, it will move all round the circle, until it reaches the other side of the wire; but then its position will be unstable, for the impetus it has already received will suffice to carry it past this point, and then it of course receives a fresh impulse, so that it may be assumed to be capable of maintaining a state of continued revolution. If the conducting wire be placed *within* the circle, the neutral points have in such case no existence, and under such circumstances the needle would perpetually revolve in the same direction, if the substance conducting the current were of such a nature as to admit of the passage of the needle across it.

Fig. 8.



31. It may be here observed, that when the arcs of oscillation of the needle are small, the influences which tend to bring the needle to its point of rest bear a very near proportion to the arcs themselves; so that the motions of the needle, in this respect, depend upon the same law as those of the pendulum; for which reason they are available in estimating the comparative intensities of the electro-magnetic influences when acting on the needle at different distances, and with greater or less quantity of current; for the force will be found to be strictly proportional to the square of the number of oscillations performed by the needle in a given time.

Fig. 9.



32. We are now in a position to comprehend, with greater facility, the combined action of an electric current upon *both* poles of a magnetic needle, balanced in the usual way upon its centre, and we shall first take the case of a current moving downward in a vertical wire *external* to the circle in which a horizontal magnet moves. If N S, fig. 9, repre-

sent a needle having its north pole pointing towards the conducting wire, W, as soon as the downward current is sent through that wire, the needle will assume a new position, S′ N′, at right angles to its former one, and *there* it will attain a state of stable equilibrium; for when it reaches that position, each pole will be influenced by a force at the *same* side of the magnet's axis, C, and the forces so acting will be equal, and possess the same mechanical advantage, inasmuch as the poles are equidistant from the conducting wire. In other words, the tangential forces being directed at right angles towards W S and W N, as shown by the arrows, oppose one another, and acting by the levers, R C and Z C, which are equal in length, are in exact equilibrium, which must be stable, for this reason, that the displacement of S′ in a northerly direction will lengthen the lever on that side, as already explained; while it will shorten the lever, R C, on the other side. The power of the longer lever will therefore preponderate, and the needle will be carried back to its former position. In like manner, if the pole, S′, were moved in a southerly direction, the force which impels the pole, N′, would in that case have the advantage acquired by the longer lever; and its effect would be to bring back the needle to its rectangular position.

33. If, under similar circumstances, the centre of the needle were unrestrained by the pivot supporting it, the resultant of the equal and contrary forces which established the needle in a position of stable equilibrium, passing through the centre of motion, C, would, of course, have no tendency to produce rotation; but when applied at the point, O, (fig. 9,) would tend to draw the conducting wire and the centre of the magnet towards each other; but if the wire were placed at the contrary side, the tangential forces would then be *towards*, instead of *from*, each other, and, in consequence, produce a resultant which would tend to draw the magnet and wire directly *from* one another, and thus produce an appearance of repulsion.

ANATOMY AND PHYSIOLOGY.

CHAPTER XX.

SECRETION AND EXCRETION.

The process by which new compounds are formed from the blood is called *secretion.* Some of these products are of use in the system, as the bile and the saliva; others are excrementitious, or intended to be discharged from it, as the sweat and the urine, and are hurtful if retained. These latter are technically distinguished as *excretions.* The two classes are not, however, strictly separable, as some substances require to be separated as excretions, and yet are made useful in their passage through the body. Thus, the bile contains a great deal of charcoal which requires to be separated from the blood; yet it is not merely poured into the intestines to be discharged, but, in mixing with the food, it produces a chemical change, as noticed in the last chapter, and causes the separation of the milky chyle, which is then presented to the mouths of the absorbents.

The secretions which serve for moistening membranes are the *mucus*, for the mucous membrane of the lungs and digestive organs; the *serum*, for the serous membranes of the chest, belly, and head; the *synovial fluid*, for the joints; the *tears*, for keeping the eye wet; and the *sebaceous* matter, as it is called, a waxy yellowish substance which is seen at the edges of the eyelids, and gives the whole surface of the body an oily appearance, when not removed by frequent washing. Those which assist in digestion are the *saliva*, the *gastric fluid*, the *pancreatic juice*, and the *bile.* There is one which is formed only at particular times—the *milk*, furnished by the mother for the nourishment of her offspring. Those which are purely excrementitious, are the *urine* and the *sweat.* Let us now examine each of them in succession, along with the apparatus in which it is formed.

Many of these fluids are prepared, without the aid of any peculiar structure which we can detect; all that we can ascertain being, that the arteries run in great profusion upon a membrane, and divide to great minuteness; and that in proportion as blood arrives at the membrane, the new fluid is produced. Others are formed in a peculiar apparatus called a *gland*, where the arteries appear to undergo a change in their own nature, and to have the power of changing the nature of their contents. In speaking of the blood, it was already remarked, that at the present day it is generally believed that the materials of all the secretions exist in it, and that the glands merely separate them from the mass of the circulating fluid. The process of secretion undoubtedly goes on under the influence of the nerves; for we find nerves distributed to all the secreting organs; and when these nerves are destroyed or injured, secretion ceases to go forward. As it depends on the presence of blood and of nervous energy, it is plainly a vital process.

The mucous and serous membranes, with their secretions, have been already spoken of in the chapters on the lungs, p. 549 of the first volume, and the digestive apparatus, p. 94 of the present one. It is only necessary here to state their chemical composition.*

The next secretion, mentioned two paragraphs back, was that of the *synovia.* This fluid, which serves for oil to the joints, and which feels very like oil between the fingers, nevertheless contains no oil, but is of a mucilaginous nature.† The synovial membrane is formed like a serous one, being a shut bag, whose surfaces are everywhere in contact; yet the surface of the membrane itself is like the mucous one lining the mouth and throat, being soft and velvety. It seems linked by a closer sympathy to the serous than to the mucous membranes, for we find the serous membranes to *sympathize* with inflamed synovial membranes; that is to say, when a joint is sorely inflamed, it is not uncommon for the serous membrane lining the belly or chest, or covering the heart, to become inflamed too, without any other cause that we can discover, than what we call the *sympathy* depending on the similarity of structure. A plan of a synovial membrane is given in vol. i., at p. 365.

All the other secretions are formed from the blood by means of peculiar *glands* which are set apart for the purpose. These differ from one another in form and structure; and yet we can see nothing in any one of them which can explain to us why its peculiar secretion is formed in *it*, and not in every other. The old physiologists fancied that each gland was like a strainer, pierced with holes of a particular size and form, so that substances of one kind passed through from the blood in one gland, but were retained in another, where something else was permitted to pass. This, however, is too mechanical an explanation. It has been already said, that the process seems to be under the regulation of the nervous influence.

Every gland consists of a congeries of small particles, from the size of a pin-head down to that of a grain of sand, each of which may justly be regarded as a perfect gland, complete in itself. For each of these particles, (represented here as greatly magnified,) will have an artery, *a*, carrying blood to it, both for its nourishment, and for the material of secre-

* MUCUS.

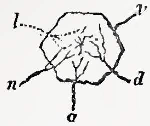
Water,	933·7
Mucus,	53·3
Chlorides of potassium and sodium,	5·6
Lactate of soda, with animal matter,	3·
Soda,	0·9
Albumen and animal matter, soluble in water, with phosphate of soda,	3·5
	1000·

SERUM.

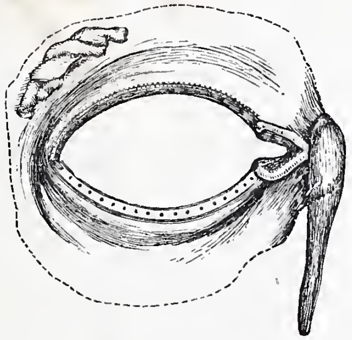
Chlorides of sodium and potassium,	6·60
Carbonate of soda,	1·65
Sulphate of potash,	0·35
Phosphate of lime, with traces of magnesia	0·60
Mucous extractive matter,	4·
Albumen,	86·8
Water,	900·
	1000·

† It is said to contain albumen, fatty matter, an animal substance soluble in water, soda, chloride of sodium and potassium, phosphate and carbonate of lime.

tion; a nerve, *n*, directing the process; a duct *d*, conveying away the product; a vein *v*, receiving the superfluous blood; and a lymphatic *l*, as every other part of the body has, for removing that part of the structure which is hourly becoming incapable of performing its functions aright. The liver is the gland on which we have been able to make the most accurate observations, as being the largest, and the most distinct in its structure, but there can be no doubt that the others are arranged much on the same principle. The blood from which the secretion is to be made is distributed to the outside of the granule which we examine; the vein passes off from the centre of the granule; and it is while the blood is passing from the outside to the centre, that, under the influence of the nerves, the separation of the new product is accomplished.



The *tears* are poured out by the *lachrymal gland*, situated in the upper and outer part of the orbit, or cavity for the eye, where it is protected from external violence, being completely within the bony rim, which is indicated in the accompanying sketch by a dotted line. It is about the size of a tamarind stone, and convex on its upper surface, so as to suit the concavity of the roof of the orbit. It consists of a multitude of yellow granules, bound together by cellular tissue, and to it are distributed the blood of a small artery and the branches of a small nerve. From this gland run from five to seven small ducts, (not represented in the figure) which convey the tears from it, perforate the mucous membrane at the outer part of the orbit, and so let the tears wash the whole surfaces of the eye and eyelids, before they escape into the nose at the inner angle. The secretion of tears is constantly going on, but in small quantity, merely for the purpose of keeping the eye moist. When any irritating substance alights upon the eye, or gets inside the eyelids,—as a particle of dust or an insect,—an increased flow of tears is immediately excited, in order to wash it away. This sudden flow, it need scarcely be remarked, is also brought on by mental emotion. A little red projection is seen between the eyelids at their inner angles, being a rudiment of the *haw* or third eyelid, which we see in all birds, and in some beasts, as the horse and cow. Its use in man is to prevent the tears from running out upon the cheek. At the projecting angle which each eyelid forms, just before its inner termination, if it be everted a little, a small hole will be seen, for the absorption of the tears. Along the two canals seen in the figure leading from these holes, the tears pass into a duct, rather larger than a crow-quill, which lies underneath the little knot which is felt on the side of the root of the nose, at the inner junction of the eyelids. This duct terminates in the nose, and conveys the tears there, after they have done all that is expected of them above. This is the reason why you blow your nose strongly, and close your eye, when any particle of dust has lodged in it, with the view of getting it drawn toward the inner angle (where it lodges, and whence it can be wiped out), by the tears which are passing into the nose through the lachrymal canals. In a dusty day, an accumulation of particles is seen in the recess beside the little red projection, ready to be wiped away.*



It is an extremely rare thing for any disease to attack the lachrymal gland; the author has, however, seen a case where it became enlarged and hard, and could be distinctly felt from the outside. On the other hand, the excreting lachrymal organs are very apt to go wrong. The duct often inflames, so that the tears cannot get down it, and run over the cheek, producing troublesome excoriations. Sometimes it suppurates and bursts; and then it requires a bit of silver wire to be introduced, and to be worn in it for some time, to keep open the passage into the nose, which has a tendency to become obliterated.

The whole *skin* is thickly covered with the orifices of minute bags, which excrete an oily matter, to keep it soft and pliant. These are more numerous in some parts than others, as in the arm-pits, and produce a disagreeable heavy effluvium, if care be not taken to keep the skin perfectly clean. This smell is particularly strong in people of colour. On the face, the orifices of these ducts are apt to become obstructed, and present little black points, projecting slightly above the level of the skin. When these are squeezed, the retained waxy matter is evacuated, assuming the shape of a little worm, from being forced through the narrow aperture. Frequently the irritation becomes greater, and a little pus forms, causing a pimple. Nothing that we know of is efficacious in keeping them back, notwithstanding all that the venders of lotions say to the contrary. Strict attention to cleanliness is the main thing; and the little points must be squeezed out daily as they appear. It is, however, the case, that in persons of intemperate habits, these spots increase and multiply to a very disagreeable extent.

In the *eyelids*, those little glands are collected into two sets, and on looking at their edges, twenty or thirty small holes will be seen in each, whence a yellow matter exudes. (In the last figure, these are seen forming the row of distinct holes; the row of still smaller ones, closely ranged together, being the apertures in which the eyelashes were set.) After cold, this matter is apt to become increased in quantity so as to glue the eyelids together in the morning, and to remain sticking in little yellow bits, while the edges of the lids themselves become inflamed. In such cases, the first rule to be attended to is, that the eyelids must not be forcibly separated, or else some of the adhering eyelashes will be pulled out; but the matter must first be softened with a rag and warm water. At night, a little eye-salve must be regularly put between the lids; and in those who are subject to this annoyance, (although they be not ill with it,) the ointment should be used at least once a-week, as a preventive measure. In scrofulous children who are ill taken care of, we often see this complaint go a shocking length, destroying all the eyelashes, causing little ulcers, and ending by rendering the edges of the lids smooth, hard, and rounded, instead of possessing their natural delicacy of structure.

The *salivary glands* have been already noticed in speaking of the mouth. There are three on each side, the *parotid* beside the ear, the *sublingual* under the tongue, and the *submaxillary* under the angle of the jaw. The saliva flows from them in great quantity during mastication, in consequence of the pressure which they undergo. Nervous feeling, or even mental emotion, has something to do with it, however; for the saliva flows from a hungry person on even seeing a piece of meat; so that there is truth in the common phrase, which describes an eager person's mouth as watering.*

The *gastric juice* has been already sufficiently treated of, under the head of digestion, p. 94. Its chemical composition is by no means satisfactorily ascertained.

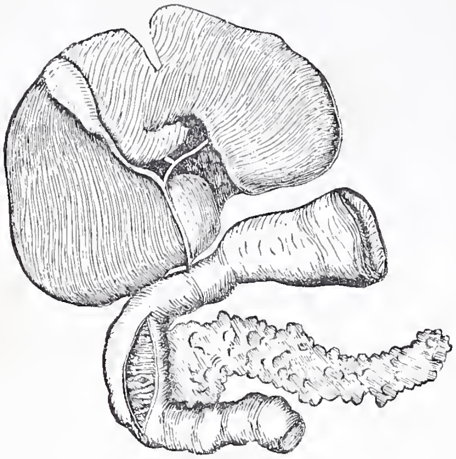
The *pancreas* is identical in structure with the salivary

* The substances found in tears by Fourcroy and Vauquelin are, water, mucus, common salt, soda, phosphate of lime, phosphate of soda.

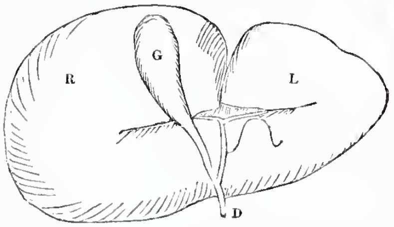
* The quantity secreted in twenty-four hours is about $7\frac{1}{2}$ ounces avoirdupois. The chemical composition of the saliva, as determined by Berzelius, is—

Water,	992·9
Salivin,	2·9
Mucus,	1·4
Alkaline chlorides,	1·7
Lactate of soda, with animal matter,	0·9
Soda,	0·9
	1000·7

glands communicating with the mouth, so that it has been called the abdominal salivary gland. It is in shape like a dog's tongue, and lies across the spine, below the stomach, and nearly surrounded by the first part of the small intestine, into which its duct perforates, close to, or along with, the entry of the one from the liver.



The *liver* is the largest gland in the body, weighing in general, from four to five pounds. It lies in the right side, close under the diaphragm, and over the stomach. It is connected by folds of the peritonæum, or lining membrane of the belly, to the neighbouring parts, these folds being called its ligaments. It is of a reddish colour, and an oval shape, its greater end being to the right, and its smaller one to the left; its convex surface directed upward to the concavity of the diaphragm, and its concave surface downward to the stomach. If examined on the surface, or by cutting a slice out of it, it appears all mottled, consisting of an infinity of little grains, each of which may be considered as a perfect gland. Each grain receives a twig from a great vein, which brings to the liver the blood which has been circulating through the rest of the belly, and each gives off a twig to the biliary ducts. The secretion in the liver differs from that in other glands, in this, that it is not from *arterial*, but from *venous* blood. The reason of this seems to be, that as bile consists in a great measure of carbon, more of the material is furnished by the venous blood. In consequence of this, a considerable share of the duty of purifying the venous blood, by taking away its carbon, is performed by the liver, and only a part of the business is left to be completed by the lungs, as described in the chapter on respiration, p. 616 of last volume.*



The liver receives a large artery for its nourishment, and branches of nerves go to it, to enable it to perform its functions. The gall-duct D, runs from the liver to the small intestine, (which is slit open, in the preceding figure, to show the aperture common to it and the pancreatic duct,) allowing the bile to combine with the food, and produce a chemical change upon it. The flow of bile is always greatest at the time when the food is passing through the bowels. At other times, it passes by a side duct into the gall-bladder G, where it is reserved till it be wanted. The figure represents the under surface of the liver; R being the right or larger lobe, and L the smaller or left.

The liver is very little subject to disease in this climate. Those persons who are said to be bilious, are so in consequence of derangement of their stomach. In hot climates, as in India, the liver is very liable to inflammation, and sometimes matter forms in it, and bursts externally. Any irritation of the liver is apt to produce jaundice, (French *jaune*, yellow,) which is just the absorption of the bile into the circulation, so that its yellow tint predominates over the red colour of the blood. The liver is also occasionally subject to general enlargement, and to a firm condensation, occasioning dropsy, principally in persons of intemperate habits; and cancerous growths now and then form in it, which can sometimes be felt by laying the hand upon the outside.

The *female breast* will be described in the article on reproduction.

The excrementitious secretions, or *excretions*, are the *urine* and the *perspiration*. These are exceedingly similar to one another in their nature, and are to a certain extent vicarious; that is, the one is able so far to supply the place of the other. Thus in winter, the perspiration is mostly suppressed, and the calls to make water are much more frequent than in summer, when the reverse is observed. Also, in those diseases of the kidneys, where no urine, or almost none is formed, the sweat becomes copious, and of a horribly offensive odour, which indicates that the salts of the blood which should pass off by the kidneys, are escaping by the way of the skin.*

No particular apparatus can be detected, having for its object the formation of the perspiration. Over the surface of the skin are scattered an infinity of holes, through which the hairs pass; and it would seem that the perspiratory ducts open into these, before they arrive at the surface.

Perspiration is constantly going on, although we may not be aware of it, and this is called the insensible perspiration. Every one knows that he perspires, and that if the perspiration be checked, as by a cold draught of air, the effect is hurtful, but few know the extent of the function which is interfered with. Lavoisier and Seguin made a series of experiments on this subject. The experimenter enclosed himself in a silk varnished bag, up to the mouth, and had himself and the bag weighed, at the commencement of the experiment. Then, at its termination, he was weighed again, still remaining in the bag. The loss of weight, of course, was lost by breathing, being the carbon and vapour which had disappeared—see vol. i., p. 616. Lastly, coming out of the bag he was weighed a third time, the loss this time, being the loss by perspiration. Of course the experimenter attended minutely to the quantity of food and drink which he swallowed, and made the requisite allowances. The result was, that the medium loss by the skin, in a day, is 32 oz. Be it remembered, that this is what we style the *insensible* perspiration. The *sensible* or *visible* sweat will come off in much greater quantity in a much shorter time. A strong man, acting as a glass-blower, will lose from 3lb. to 4lb. in an hour. There is no wonder that these work-people should be so given to drinking;—although we may certainly regret that their habitual drink should be so strong.

This perspiration, it has been said, is constantly going on. In *dry* weather it is not observed, because it evaporates immediately. In *damp* weather, it stands upon one's brow in drops, because it does not get evaporated. In *hot* weather, it wets one all over, because much more of it is poured out, for the purpose of keeping down the heat, which would otherwise be insupportable. It is in imitation of this natural

* The bile contains, according to Berzelius,—

Water,	904·4
Biliary matter and fat,	80·
Mucus of gall-bladder,	3·
Extract of meat, common salt, lactate of soda,	7·4
Soda,	4·1
Phosphates of soda and lime, and substances insoluble in alcohol	1·1
	1000·

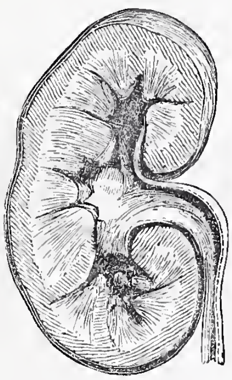
* Dr. Thomson says that it contains the lactates of soda, potash, lime, and magnesia, together with common salt, sal-ammoniac, and traces of chloride of potassium, phosphate of soda, and phosphate of lime; also animal matter, insoluble in alcohol.

process, that we give a sweating powder to a man labouring under a fever; he sweats all night, and in the morning he is found cooler, and the fever has in a great measure left him.

The application of cold chills the surface, represses the cutaneous exhalation, and drives the blood inward, in too great quantity, upon the lungs, or some other weak part, which is apt to suffer. This is what is meant by *taking cold.* It is no wonder that serious consequences should ensue, where 2500 square inches, (for that is the superficial extent of the skin) have their secretion repressed, and the blood that should furnish it, driven in upon the internal organs. Consequently, to relieve the feeling of this *taking cold,* the plain way is to bring back heat to the skin;—to bathe the feet, or take a general hot bath, to swallow a hot gruel, or a sweating powder; and on turning-in to bed, to put on an additional blanket.

From what has been said of the quantity of matter which passes through the skin, it will be plain of what importance cleanliness is. To maintain this, the body should be spunged every day from head to foot, and rubbed dry with a coarse towel.

The *kidneys* are two in number, situated in the belly, one on each side of the spine. Each kidney is of an oval shape, with a notch in the side next the spine. Into this notch the vessels enter. A large artery furnishes the materials for the urine; a duct conveys it away when formed; and a vein removes the superfluous blood. In the figure, one-half of a kidney is shown, cut perpendicularly through the middle, so as to show its internal structure. From eight to fourteen cones are seen, consisting mostly of straight vessels, projecting from that part of the organ to which the blood is most profusely distributed, from whose points the urine distils, drop by drop, into three membranous funnels. These three funnels unite in the great bag of the kidney, from which the pipe called the *ureter* leads down to the bladder. The bladder is seated in the fore part of the cavity at the lower part of the belly called the *pelvis;* it has two openings behind, for the two ureters, perforating very obliquely, so as to prevent regurgitation. From its front and lower part, the *urethra* or water-pipe passes out, through which the urine is to be expelled from the body.



The *urine* is a highly animalized fluid, as might at once be supposed from the rapidity with which it passes into putrefaction. It appears to contain a great deal of the waste, or worn-out parts of the body, particularly the saline particles. These salts consist of potash and soda, ammonia, (commonly called hartshorn) which gives it its pungent smell, and a substance called *urea,* on which many of its peculiarities depend. In disease, the urine is affected in various ways. Sometimes its quantity is increased or diminished. In the healthy state, a full-grown man voids nearly three pints of urine in a day, the quantity varying in an inverse proportion to the perspiration, and in direct proportion to the drink taken, and to individual peculiarities. In dropsy, the quantity is reduced to one or two wine-glassfuls; and in a very curious disease called *diabetes,* it is sometimes increased to so much as thirty pints. It varies also in its qualities. In the last-mentioned disease, it becomes sweet, its salts are changed into sugar, which may be crystallized from it, pure and white. Its salts may also become too great in quantity for the water to dissolve, and then they fall down to the bottom of the bladder, and constitute a sediment, which sometimes concretes into stones. When stones are once formed in the bladder, they produce dreadful irritation, and require to be removed by an operation. Stone has long been a capital subject for quacks, who sell medicines which they pretend can dissolve it while in the bladder. All this, however, is mere pretension; for anything strong enough to dissolve the stone, would first destroy the coats of the bladder. Their medicines, in general, contain soda, which passes into the urine, and has the effect of coating over the stone, and so rendering it for the time less irritating, but lays the foundation for still greater suffering, by increasing its bulk. Nothing indeed can be trusted for a cure, but the removal of the offending body, by the surgical operation of lithotomy.*

DESCRIPTION OF THE TITHONOMETER,

AN INSTRUMENT FOR MEASURING THE CHEMICAL FORCE OF THE INDIGO-TITHONIC RAYS.†

By John W. Draper, M.D.,

Professor of Chemistry in the University of New York.

I have invented an instrument for measuring the chemical force of the tithonic rays which are found at a maximum in the indigo space, and which from that point gradually fade away to each end of the spectrum. The sensitiveness, speed of action, and exactitude of this instrument, will bring it to rank as a means of physicial research with the thermo-multiplier of M. Melloni.

The means which have hitherto been found available in optics for measuring intensities of light, by a relative illumination of spaces or contrast of shadows, are admitted to be inexact. The great desideratum in that science is a photometer, which can mark down effects by movements over a graduated scale. With those optical contrivances may be classed the methods hitherto adopted for determining the force of the tithonic rays by stains on Daguerrotype plates, or the darkening of sensitive papers. As deductions drawn in this way depend on the *opinion* of the observer, they can never be perfectly satisfactory, nor bear any comparison with thermometric results.

Impressed with the importance of possessing for the study of the properties of the tithonic rays some means of accurate measurement, I have resorted in vain to many contrivances; and, after much labour, have obtained at last the instrument which it is the object of this paper to describe.

The tithonometer consists essentially of a mixture of equal measures of chlorine and hydrogen gases, evolved from, and confined by, a fluid which absorbs neither. This mixture is kept in

* Dr. Thomson, in his *Animal Chemistry,* gives the following analysis of urine:—

Urate of ammonia,	0·298
Sal-ammonia,	0·459
Sulphate of potash,	2·112
Chloride of potassium,	3·674
Chloride of sodium,	15.060
Phosphate of soda,	4·267
Phosphate of lime,	0·209
Acetate of soda,	2·770
Urea, with colouring matter,	23·640
	52·489
Water, with a free acid, probably the lactic,	947·511
	1000·

† It may be necessary to remind the reader, that in analyzing the solar beam, all parts of it are not found equally active in producing chemical effects; the conclusion, indeed, now very generally admitted by those who have investigated the subject closely is, that in the solar beam there are three distinct kinds of rays—namely, those possessing heating properties, which are termed the *calorific* rays; those producing the sensation of light, and which we called the *luminous* rays; and, lastly, those producing chemical effects, as exemplified in photogenic processes, and the union of chlorine and hydrogen when exposed in mixture to the sun's light; and which Dr. Draper proposes to call *tithonic* rays. In this he adopts the idea of peculiar matters of light and heat, and considers that the chemical effects are produced by a peculiar material agent, which he terms *Tithonicity.* *Actinism* is the term more generally used, and is less liable to objection, as explained in our first chapter on Photography. The name applied by Dr. Draper may hereafter be found inappropriate, and it does not appear to be in the meantime absolutely needed; but the researches with which it is connected are highly valuable, and the instrument described in the following paper will undoubtedly, either in its present or some modified form, be found invaluable in future investigations respecting the chemical properties of light.

a graduated tube, so arranged that the gaseous surface exposed to the rays never varies in extent, notwithstanding the contraction which may be going on in its volume, and the muriatic acid resulting from its union is removed by rapid absorption.

The theoretical conditions of the instrument are therefore sufficiently simple; but, when we come to put them into practice, obstacles which appear at first sight insurmountable are met with. The means of obtaining chlorine are all troublesome; no liquid is known which will perfectly confine it; it is a matter of great difficulty to mix it in the true proportion with hydrogen, and have no excess of either. Nor is it at all an easy affair to obtain pure hydrogen speedily, and both these gases diffuse with rapidity through water into air.

Without dwelling further on the long catalogue of difficulties which is thus to be encountered, I shall first give an account of the instrument in the form I now use it, which will show to what an extent all those difficulties are already overcome.

Description of the instrument. First, of the glass part.—The tithonometer consists of a glass tube bent into the form of a siphon, in which chlorine and hydrogen can be evolved from muriatic acid, containing chlorine in solution, by the agency of a voltaic current. It is represented by fig. 1, where *a b c* is a

Fig. 1.

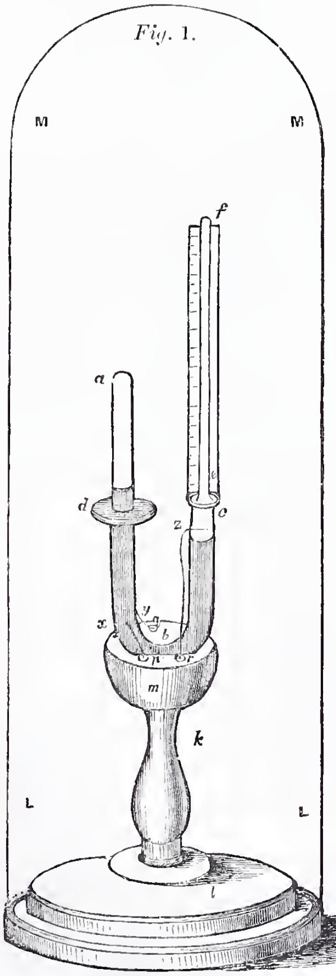


Fig. 3.

Fig. 2.

clear and thin tube, four-tenths of an inch external diameter, closed at the end, *a*. At *d*, a circular piece of metal, an inch in diameter, which may be called the stage, is fastened on the tube, the distance from *d* to *a* being 2·9 inches. At the point, *x*, which is two inches and a quarter from *d*, two platina wires, *x* and *y*, are fused into the glass, and entering into the interior of the tube, are destined to furnish the supply of chlorine and hydrogen; from the stage, *d*, to the point, *b*, the inner bend of the tube is 2·6 inches, and from that point to the top of the siphon *c*, the distance is three inches and a half. Through the glass at *z*, three quarters of an inch from *c*, a third platina wire is passed; this wire terminates in the little mercury cup *r*, and *x* and *y* in the cups *p* and *q* respectively.

Things being thus arranged, the instrument is filled with its fluid, prepared, as will presently be described; and as the legs *a b*, *b c*, are not parallel to each other, but include an angle of a few degrees, in the same way that Ure's eudiometer is arranged, there is no difficulty in transferring the liquid to the sealed leg. Enough is admitted to fill the sealed leg and the open one partially, leaving an empty space, to the top of the tube at *c*, of two and three quarter inches.

A stout tube, six inches long and one-tenth of an inch interior diameter, *e f*, is now fused on at *c*. Its lower end opens into the main siphon tube; its upper end is turned over at *f*, and is narrowed to a fine termination, so as barely to admit a pin, but is not closed. This serves to keep out dust, and in case of a little acid passing out, it does not flow over the scale and deface the divisions. At the back of this tube a scale is placed, divided into tenths of an inch, being numbered from above downward. Fifty of these divisions are as many as will be required. Fig. 2 shows the termination of the narrow tube bent over the scale.

From a point one-fourth of an inch above the stage *d*, downwards beyond the bend, and to within half an inch of the wire *z*, the whole tube is carefully painted with India ink so as to allow no light to pass; but all the space, from a fourth of an inch above the stage *d*, to the top of the tube *a*, is kept as clear and transparent as possible. This portion constitutes the sentient part of the instrument. A light metallic or pasteboard cap, A D, fig. 3, closed at the top and open at the bottom, three inches long and six-tenths of an inch in diameter, blackened on its interior, may be dropped over this sentient tube; it being the office of the stage *d* to receive the lower end of the cap when it is dropped on the tube so as to shut out the light.

The foot of the instrument, *k l*, is of brass, it screws into the hemispherical block *m*, which may be made of hard wood or ivory; in this three holes, *p q r*, are made to serve as mercury cups; they should be deep and of small diameter, that the metal may not flow out when it inclines for the purpose of transferring. A brass cylindrical cover L M, L M, may be put over the whole; when it is desirable to preserve it in total darkness, it should be blackened without.

Secondly, of the Fluid Part.—The fluid from which the mixture of chlorine and hydrogen is evolved, and by which it is confined, is yellow commercial muriatic acid, holding such a quantity of chlorine in solution that it exerts no action on the mixed gases as they are produced. From the mode of its preparation it always contains a certain quantity of chloride of platina, which gives it a deep golden colour, a condition of considerable incidental importance.

When muriatic acid is decomposed by voltaic electricity its chlorine is not evolved, but is taken up in very large quantity and held in solution; perhaps a bichloride of hydrogen results. If through such a solution hydrogen gas is passed in minute bubbles, it removes with it a certain proportion of the chlorine. From this therefore it is plain, that muriatic acid thus decomposed will not yield equal measures of chlorine and hydrogen unless it has been previously impregnated with a certain volume of the former gas. Nor is it possible to obtain that degree of saturation by voltaic action, no matter how long the electrolysis is continued, if the hydrogen is allowed to pass through the liquid.

Practically, therefore, to obtain the tithonometric liquid, we are obliged to decompose commercial muriatic acid in a glass vessel, the positive electrodes being at the bottom of the vessel and the negative at the surface of the liquid. Under these circumstances, the chlorine as it is disengaged is rapidly taken up, and the hydrogen being set free without its bubbles passing through the mass, the impregnation is carried to the point required.

Although this chlorinated muriatic acid cannot, of course, be kept in contact with the platina wires without acting on them, the action is much slower than might have been anticipated. I have examined the wires of tithonometers that had been in active use for four months, and could not perceive the platina sensibly destroyed. It is well, however, to put a piece of platina

foil in the bottle in which the supply of chlorinated muriatic acid is kept; it communicates to it slowly the proper golden tint.

The liquid, being impregnated with chlorine in this manner until it exhales the odour of that gas, is to be transferred to the siphon *a b c* of the tithonometer, and its constitution finally adjusted as hereafter shown.

Thirdly, of the Voltaic Battery.—The battery, which will be found most applicable for these purposes, consists of two Grove's cells, the zinc surrounding the platina.

The following are the dimensions of the pairs which I use. The platina plate is half an inch wide and two inches long; it dips into a cylinder of porous biscuit-ware of the same dimensions, which contains nitric acid. Outside this porous vessel is the zinc, which is a cylinder one inch diameter, two inches long, and two-tenths thick; it is amalgamated. The whole is contained in a cup, two inches in diameter and two deep, which also receives the dilute sulphuric acid.

The force of this battery is abundantly sufficient both for preparing the fluid originally and for carrying on the tithonometric operations; it can decompose muriatic acid with rapidity, and will last with ordinary care for a long time.

Before passing to the mode of using the tithonometer, it is absolutely necessary to understand certain theoretical conditions of its equilibrium; to these in the next place I shall revert.

Theoretical Conditions of Equilibrium.—The tithonometer depends for its sensitiveness on the exact proportion of the mixed gases. If either one or the other is in excess, a great diminution of delicacy is the result. The comparison of its indications at different times depends on the certainty of evolving the gases in exact, or at all events, known proportions.

Whatever, therefore, affects the constitution of the sentient gases alters at the same time their indications. Between those gases and the fluid which confines them certain relations subsist, the nature of which can be easily traced. Thus, if we had equal measures of chlorine and hydrogen, and the liquid not saturated with the former, it would be impossible to keep them without change, for by degrees a portion of chlorine would be dissolved, and an excess of hydrogen remain; or, if the liquid was overcharged with chlorine, an excess of that gas would accumulate in the sentient tube.

It is absolutely necessary, therefore, that there should be an equilibrium between the gaseous mixture and the confining fluid.

As has been said, when muriatic acid is decomposed by a voltaic current, all the chlorine is absorbed by the liquid and accumulates therein, the hydrogen bubbles, however, as they rise, withdraw a certain proportion, and hence pure hydrogen passed up through the tithonometric fluid becomes exceedingly sensitive to the light.

There are certain circumstances connected with the constitution and use of the tithonometer which continually tend to change the nature of its liquid. The platina wires immersed in it by slow degrees give rise to a chloride of platina. It is true that this takes place very gradually, and by far the most formidable difficulty arises from a direct exhalation of chlorine from the narrow tube *e f*; for each time that the liquid descends, a volume of air is introduced, which receives a certain amount of chlorine which with it is expelled the next time the battery raises the column to zero; and this, going on time after time, finally impresses a marked change on the liquid. I have tried to correct this in various ways, as by terminating the end *f* with a bulb; but this entails great inconvenience, as may be discovered by any one who will reflect on its operation.

When by the battery we have raised the index to its zero point, if the gas and liquid are not in equilibrio, that zero is liable to a slight change. If there be hydrogen in excess the zero will rise,—if chlorine, the zero will fall.

In making what will be termed "interrupted experiments," we must not too hastily determine the position of the index on the scale at the end of a trial. It is to be remembered that the cause of movement over the scale arises from a condensation of muriatic acid; but that condensation, though very rapid, is not instantaneous. Where time is valuable, and the instrument in perfect equilibrium, this condensation may be instantaneously effected, by simply inclining the instrument, so that its liquid may pass down to the closed end, *a*, but not so much as to allow gas to escape into the other leg; the inclination of the two legs to each other makes this a very easy manipulation, and the gas thus brought into contact with an extensive liquid surface yields up its muriatic acid in a moment.

Directions for using the Tithonometer. Preliminary adjustment.—Having transferred the liquid to the sealed end of the siphon, and placed the cap on the sentient extremity, the voltaic battery being prepared, the operator dips its polar wires into the cups *p q*, which are in connexion with the wires *x y*. Decomposition immediately takes place, chlorine and hydrogen rising through the liquid, and gradually depressing it, whilst of course a corresponding elevation takes place in the other limb—this operation is continued until the liquid has risen to zero. It takes but a few seconds for this to be accomplished.

The polar wires having been disengaged, the tithonometer is removed opposite a window, care being taken that the light is not too strong. The cap is now lifted off the sentient extremity *a d*, and immediately the liquid descends. This exposure is allowed to continue, and the liquid suffered to rise as much as it will to the end *a*. And now, if the gases have been properly adjusted, an entire condensation will take place, the sentient tube *a d* filling completely. In practice this precision is not however obtained, and if a bubble as large as a peppercorn be left, the operator will be abundantly satisfied with the sensitiveness of his instrument. Commonly, at first, a large residue of hydrogen gas, occupying perhaps an inch or more, will be left. It is to be understood that even this large surplus will disappear in a few hours by absorbing chlorine. But this is not to be waited for; as soon as no further rise takes place in a minute or two, the siphon is to be inclined on one side, and the residue turned out into the open leg.

Now, recurring to what has been said on the equilibrium, it is plain that this excess of hydrogen arises from a want of chlorine in the tithonometric liquid. A proper quantity must therefore be furnished by proceeding as follows.

The sentient tube being filled with the liquid by inclination, connect the polar wires with *p q*, as before. These may be called *generating wires*. Allow the liquid to rise in *b c*, until the third platina wire *z*, which may be called the *adjusting wire*, is covered an eighth of an inch deep. Then remove the negative wire from the cup *p* into the cup *r*, and now the conditions for saturating the liquid are complete; hydrogen escaping away from the surface of the liquid at *z*, and chlorine continually accumulating and dissolving between *x* and *d*. This having been carried on for a short time, the gas in *a d* is to be turned out by inclination and the instrument recharged. That a proper quantity is evolved is easily ascertained by allowing total condensation to take place, and observing that only a small bubble is left at *a*.

It will occasionally happen in this preliminary adjustment, that an excess of chlorine may arise from continuing the process too long. This is easily discovered by its greenish-yellow tint, and is to be removed by inclining the instrument and turning it out. Thus adjusted, everything is ready to obtain measures of any effect, there being two different methods by which this can be done,—1st, by continuous observation; 2d, by interrupted observation.

Of the method of continuous observation.—This is best described by resorting to an example. Suppose, therefore, it is required to prove that the effect on the tithonometer is proportional to its time of exposure.

Put on the cap of the sentient tube *a d*, connect the polar wires with *p q*, and raise the liquid to zero.

Place the tithonometer so that its sentient tube will receive the rays properly.

At a given instant, marked by a seconds watch, remove the cap, A D, and the liquid at once begins to descend. At the end of the first minute read off the division over which it is passing. Suppose it is 7. At the end of the second do the same; it should be 14; at the end of the third 21, &c., &c. This may be done until the fiftieth division is reached, which is the terminus of the scale.

Recharge the tube by a momentary application of the polar wires; but it is convenient first to remove any excess of muriatic acid gas in the sentient tube, by allowing it time for condensation; or, if that be inadmissible, by inclining a little on one side, so as to give an extensive liquid contact.

Of the method of interrupted observation.—It frequently happens that observations cannot be had during a continuous

descent, as when changes have to be made in parts of apparatus or arrangements. We have then to resort to interrupted observations.

This method requires that the gas and liquid should be well adjusted, so that no change can arise in volume when extensive contact is made by inclination.

The tithonometer being charged, place it in a proper position. At a given instant remove its cap, and the liquid descends. When the time marked by a seconds' watch has elapsed, drop the cap on the sentient tube. The liquid simultaneously pauses in its descent, but does not entirely stop; for a little uncondensed muriatic acid still exists, which is slowly disappearing in the sentient tube. Now, incline the instrument for a moment on one side, so that the liquid may run up to the cord *a*, but not so much as to let any gas escape. Restore it to its position and read off on the scale. It is then ready for a second trial.

The difference between continuous and interrupted observation is this, that in the latter we pause to wash out the muriatic acid, and though this is effected by the simplest of all possible methods, continuous observations are always to be preferred when they can be obtained.

Of the sensitiveness of the Tithonometer.—In a course of experiments on the union of chlorine and hydrogen, some of which were read at one of the meetings of the British Association, I found that the sensitiveness of that mixture had been greatly underrated. The statement made in the books of chemistry, that artificial light will not affect it, is wholly erroneous. The feeblest gleams of a taper produce a change. No further proof of this is required than the tables given in this communication, in which the radiant source was an oil-lamp. For speed of action, no tithonographic compound can approach it; a light, which perhaps does not endure the millionth part of a second, affects it energetically, as will be hereafter shown.

The following illustrations will show that the tithonometer is promptly affected by rays of the feeblest intensity, and of the briefest duration.

When, on the sentient tube of the tithonometer, the image of a lamp formed by a convex lens is caused to fall, the liquid instantly begins to move over the scale, and continues its motion as long as the exposure is continued. It does not answer to expose the tube to the direct emanations of the lamp without first absorbing the radiant heat, or the calorific effect will mask the true result. By the interposition of a lens this heat is absorbed, and the tithonic rays alone act.

If a tithonometer is exposed to daylight coming through a window, and the hand, or a shade of any kind—is passed in front of it, its movement is *in an instant* arrested; nor can the shade be passed so rapidly that the instrument will fail to give the proper indication.

The experimenter may further assure himself of the extreme sensitiveness of this mixture by placing the instrument before a window, and endeavouring to remove and replace its screen so quickly that it shall fail to give any indication; he will find that it cannot be done.

Charge a Leyden phial, and place the tithonometer at a little distance from it, keeping the eye steadily fixed on the scale; discharge the jar, and the rays from the spark will be seen to exert a very powerful effect, the movement taking place and ceasing in an instant.

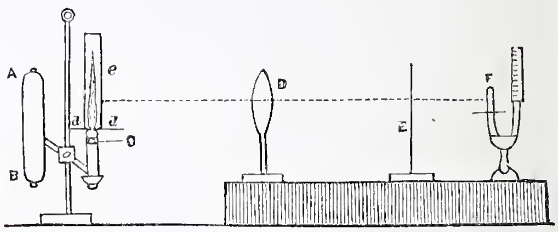
This remarkable experiment not only serves to prove the sensitiveness of the tithonometer, but also brings before us new views of the powers of that extraordinary agent electricity. That energetic chemical effects can thus be produced at a distance by an electric spark in its momentary passage—effects which are of a totally different kind from the common manifestations of electricity—is thus proved. These phenomena being distinct from those of induction or molecular movements taking place in the line of discharge, are of a radiant character, and due to the emission of tithonicity; and we are led at once to infer that the well-known changes brought about by passing an electric spark through gaseous mixtures, as when oxygen and hydrogen are combined into water, or chlorine and hydrogen into muriatic acid, arise from a very different cause than those condensations and percussions by which they are often explained, a cause far more purely chemical in its kind. If chlorine and hydrogen can be made to unite silently by an electric spark passing outside the vessel which contains them, at a distance of several inches, there is no difficulty in understanding why a similar effect should take place with a violent explosion, when the discharge is made through their midst; nor how a great many mixtures may be made to unite under the same treatment. A flash of lightning cannot take place, nor an electric spark be discharged, without chemical changes being brought about by the radiant matter emitted.

Of the exactness of the indications.—The foregoing examples may serve to illustrate the extreme sensitiveness of the tithonometer; I shall next furnish proofs that its indications are exactly proportional to the quantities of light incident on it.

As it is necessary, owing to the variable force of daylight, to resort to artificial means of illumination, it will be found advantageous to employ the following method of obtaining a flame of suitable intensity.

Let A B, fig. 4, be an Argand oil lamp of which the wick is c

Fig 4.



Over the wick at a distance of half an inch or thereabouts place a plate of thin sheet copper, three inches in diameter, perforated in its centre with a circular hole of the same diameter as the wick, and concentric therewith. This piece of copper is represented at *d d;* it should have some contrivance for raising or depressing it through a small space, the proper height being determined by trial. On this plate, the glass cylinder *e*, an inch and three quarters in diameter, and eight or ten inches long, rests.

When the lamp is lighted, provided the distance between the plate *d d* and the top of the wick is properly adjusted, on putting on the glass cylinder the flame instantly assumes an intense whiteness; by raising the wick it may be elongated to six inches or more, and becomes exceedingly brilliant. Lamps constructed on these principles may be purchased in the shops. I have, however, contented myself with using a common Argand study-lamp, supporting the perforated plate *d d* at a proper altitude by a retort stand. It will be easily understood that the great increase of light arises from the circumstance that the flame is drawn violently through the aperture in the plate by the current established in the cylinder.

As much radiant heat is emitted by this flame, in order to diminish its action, and also to increase the tithonic effect, I adopt the following arrangement. Let A B, fig. 4, be the lamp; the rays emitted by it are received on a convex lens D, four inches and three-quarters in diameter, that which I use being the large lens of a lucernal microscope. This placed at a distance of twenty-one inches from the lamp, gives an image of the flame at a distance of thirteen inches, which is received on the sentient tube of the tithonometer—F; between the tithonometer and the lens there is a screen E.

Things being thus arranged, and the lamp lighted so as to give a flame about three inches and a half long, the experiments may be proceeded with. It is convenient always to work with the flame at a constant height, which may be determined by a mark on the glass cylinder. At a given instant, by a seconds-watch, the screen E is removed, and immediately the tithonometer begins to descend. When the first minute is elapsed the position on the scale is read off and registered; at the close of the second minute the same is done, and so on with the third, &c. And now, if those numbers be compared, casting aside the first, they will be found equal to one another, as the following table of experiments, made at different times, and with different instruments, shows. The reader will observe, that the numbers in each column do not represent the degrees as measured from the top of the scale, but merely the actual number of divisions through which the fluid passes in each successive second:—

TABLE I.—*Showing that when the radiant source is constant, the amount of movement in the tithonometer is directly proportional to the times of exposure.*

Time.	EXPERIMENTS.				
	1.	2.	3.	4.	5.
″					
30	7·00	7·00	10·25	...	5·25
60	8·00	7·75	11·50	11·75	6·50
90	7·50	8·00	11·50	...	6·25
120	7·75	7·75	11·50	13·00	6·00
150	7·75	7·25	...	...	6·00
180	...	...	...	12·00	6·00
210	...	...	...	...	6·00
Mean	7·60	7·55	11·19	12·25	6·00

From this it will be perceived that, taking the first experiment as an example, if at the end of 30 seconds the tithonometer has moved 7·00, at the end of 60″ it has moved 8·00 more, at the end of 90″, 7·50 more, at the end of 120″, 7·75 more; the numbers set down in the vertical column representing the amount of motion for each thirty seconds. And, when it is recollected that the readings are all made with the instrument in motion, the differences between the numbers do not greatly exceed the possible errors of observation. It may be remarked that the third and fourth experiments were made with a different lamp.

Though a certain amount of radiant heat, from a source so highly incandescent as that here used, will pass the lens, its effects can never be mistaken for those of the tithonic rays. This is easily understood, when we remember that the effect of such transmitted heat would be to expand the gaseous mixture, but the tithonic effect is to contract it.

Next, I shall proceed to show that the indications of the tithonometer are strictly proportional to the quantity of rays that have impinged upon it; a double quantity producing a double effect, a triple quantity a threefold effect, &c.

A slight modification in the arrangement (fig. 4) enables us to prove this in a satisfactory way. The lens D, being mounted in a square wooden frame, can easily be converted into an instrument for delivering at its focal point, where the sentient tube is placed, measured quantities of the tithonic rays, and thus becomes an invaluable auxiliary in those researches which require known and predetermined quantities of tithonicity to be measured out. The principle of the modification is easily apprehended. If half the surface of the lens be screened by an opaque body, as a piece of blackened cardboard, of course only half the quantity of rays will pass which would have passed had the screen not been interposed. If one-fourth of the lens be left uncovered, only one-fourth of the quantity will pass; but in all these instances the focal image remains the same as before. By adjusting, therefore, upon the wooden frame of the lens, two screens—the edges of which pass through its centre, and are capable of rotation upon that centre—we shall cut off all light when the screens are applied edge to edge; we shall have 90° when they are rotated so as to be at right angles, and 180° when they are superposed with their edges parallel. Thus, by setting them in different angular positions, we can gain all quantities from 0° up to 180°, and, by removing them entirely away reach 360°.

It will be understood that the effect of the instrument is to give an image of a visible object of which the intensity can be made to vary at pleasure in a known proportion.

In order, therefore, to prove that the indications of the tithonometer are proportional to the quantity of impinging rays, place this *measuring lens* in the position D, setting its screens at an angle of 90°. Remove the screen E, and determine the effect on the tithonometer for one minute. At the close of the minute, and without loss of time, turn one of the screens so as to give an angle of 180°, and now the effect will be found double what it was before, as in the following table, in which it will be seen that the numbers are proportional to the degrees:—

TABLE II.—*Showing that the indications of the tithonometer are proportional to the quantity of incident rays.*

Quantities.	EXPERIMENT 1.		EXPERIMENT 2.	
	Observed.	Calculated.	Observed.	Calculated.
90°	2·18	2·22	2·69	2·75
180	4·27	4·45	5·75	5·50
270	6·70	6·67	8·25	8·25
360	8·90	8·90	11·00	11·00

I have stated in the commencement of this paper, that the action upon the tithonometer is limited to a ray which corresponds in refrangibility to the indigo, or rather, that in the indigo space its maximum action is found. The following table serves at once to prove this fact, and also to illustrate the chemical force of the different regions of the spectrum:—

TABLE III.—*Showing that the maximum for the tithonometer is in the indigo space of the spectrum.*

Space.	Ray.	Force	Space.	Ray.	Force.
0	Extreme red	·33	8	Blue-indigo...	204·00
1	Red..........	·50	9	Indigo........	240·00
2	Orange.......	·75	10	Violet.........	121·00
3	Yellow........	2·75	11	Violet,........	72·00
4	Green.........	10·00	12	Violet.........	48·00
5	Green-blue...	54·00	13	Violet.........	24·00
6	Blue.........	108·00	14	Extra-spectral	12·00
7	Blue.........	144·00			

In this table the spaces are equal; the centre of the red, as insulated by cobalt blue glass, is marked as unity; the centre of the yellow, insulated by the same, being marked 3; the intervening region being divided into two equal spaces, and divisions of the same value carried on to each end of the spectrum.

As instruments will no doubt be hereafter invented for measuring the phenomena of different classes of rays, it may prove convenient to designate the precise ray to which they apply. Perhaps the most simple mode is to affix the name of the ray itself. Under that nomenclature the instrument described in this paper would take the name of Indigo-tithonometer.

There is no difficulty in adapting this instrument to the determination of questions relating to absorption, reflection, and transmission. Thus I found that a piece of colourless French plate-glass transmitted 866 rays out of 1000.

I have extended this paper to so great a length that many points on which remarks might have been made must be passed over. It is scarcely necessary to say that the sentient tube must be *uniformly* and perfectly clean. As a general rule also, the first observation may be cast aside, for reasons which I need not now explain. Further, it is to be remarked, as it is an essential principle that during different changes of volume of the gas its exposed surface must never vary in extent, the liquid is not to be suffered to rise above the blackened portion at *d*. If the measures of the different parts be such as have been here given, this cannot take place; for the liquid will fall below the fiftieth division before its other extremity rises above *d*.

The same original volume of gas in *a d* will last for a long time, as we keep replenishing it as often as the fiftieth division is reached.

The experimenter cannot help remarking, that on suddenly exposing the sentient tube to a bright light, *the liquid for an instant rises* on the scale, and on dropping the cap *in an instant falls*. This important phenomenon may be strikingly seen under the action of an electric spark.

In conclusion, as to comparing the tithonometric indication at different times, if the gases have the same constitution, the observations will compare; and if they have not, the value can from time to time be ascertained by exposure to a lamp of constant intensity. To this method I commonly resort.

From the space occupied in this description, the reader might be disposed to infer that the tithonometer is a very complicated instrument, and difficult to use. He would form, however, an erroneous opinion. The preliminary adjustment can be made in five minutes, and with it an extensive series of measures obtained. These long details have been entered into that the theory of the instrument may be known, and optical artists construct it without difficulty. Though surprisingly sensitive to the action of the indigo ray, it is as manageable by a careful experimenter as a common differential thermometer.

MATHEMATICS.

PRINCIPLES OF ALGEBRA.

Chapter III.—Division.

22. Division in algebra has the same object as in arithmetic: it is an operation by which we are enabled to discover one of the factors of a given product when the other factor is known; and from this definition it follows, that the quotient multiplied by the divisor ought to reproduce the dividend.

23. In applying this fundamental idea of division to simple quantities, we perceive (from Art. 11, p. 161) that the dividend being formed of the factors composing the divisor and the quotient, this last must be that quantity which is left when the divisor is suppressed in the dividend. For instance, to divide $a b$ by a; here the dividend $a b$ is composed of a, the divisor, and another factor b; and this last, namely b, agreeably to our definition, is the quotient of $a b$, divided by a; and b may be found by simply suppressing a the divisor, in the dividend $a b$.

24. We might reason in the same manner respecting any other example of the same kind; accordingly we conclude that to effect the division of a simple quantity, where there has been already a multiplication by the quantity which is made the divisor, we must suppress in the dividend all the factors which compose the divisor, and take the remaining part of the dividend as the quotient sought.

Thus $a b c$ divided by a is $b c$; by b is $a c$; by c is $a b$;
. . by $a b$ is c; by $a c$ is b; by $b c$ is a.

The rule obviously comprises numerical coefficients as exemplified in some of the following instances.

Dividond.	Divisor.	Quotient.	Dividend.	Divisor.	Quotient.
$4abcd$	$2ac$	$2bd$	$15abbccd$	$abbccd$	15
$10aabdd$	$5ad$	$2abd$	$15aaxxx$	$5axx$	$3ax$
$12aappx$	$6app$	$2ax$	$2abbxxy$	$4axxy$	$\frac{1}{2}bb$
$2abbccdd$	$abcd$	$2bcd$	$2\frac{1}{2}aaaa$	$\frac{1}{2}aaa$	$5a$

25. In the extended arithmetical sense which considers a *time* as well as *times*, any quantity admits of division by any other. Thus, 9 contains 6, a time and half a time; or the quotient of 9 divided by 6, is $1\frac{1}{2}$. The appellation *divisible* is nevertheless applied, not to any quantity as compared with any other, but only as compared with such quantities as are contained an exact number of times in the quantity proposed for division. Thus, 9 is said to be divisible by 3, and not divisible by 6. Or, by divisible is meant that the division can be effected without introducing fractions into the result. In this sense, $a b$ is not divisible by $a c$; for the dividend $a b$ does not contain the factor c, which is found in the divisor. But since the quotient, whatever it may be, is not altered when the dividend and divisor are both multiplied or both divided by the same quantity; that is, since $m a \div m b$ is the same as $a \div b$, we conclude that $a b \div a c$ is the same as $b \div c$, which we agree to write $\frac{b}{c}$ and to call it the quotient of $a b$ divided by $a c$; in other words $a b$ contains $a c$ as many times as $\frac{b}{c}$ contains 1. And again, since the quotient multiplied by the divisor must reproduce the dividend,

$$\text{therefore } \frac{b}{c} \times a c = \frac{a b c}{c} = a b.$$

26. From this it appears, that to divide when the divisor is not exactly contained in the dividend, we must suppress all the factors which are common to the divisor and dividend, and write the remaining parts in the form of a fraction as the quotient sought.

For example, to divide $12\, a b c d$ by $8\, a c d x$; here $12\, a b c d = 4\, a c d \times 3\, b$ and $8\, a c d x = 4\, a c d \times 2\, x$; therefore $12\, a b c d \div 8\, a c d x$ is the same as $3\, b \div 2\, x = \frac{3\, b}{2\, x}$ or $\frac{12\, a b c d}{8\, a c d x} = \frac{4\, a c d \times 3\, b}{4\, a c d \times 2\, x} = \frac{3\, b}{2\, x}$ the quotient sought.

It does not follow that a quantity because it has the fractional form $\frac{a}{b}$ is, arithmetically considered, a fraction; or that a quantity, because it has the integral form $a b$ is, arithmetically considered, a whole number. As formerly observed, letters are employed in algebra to represent quantities generally, and therefore fractions as well as whole numbers. An expression therefore which is fractional, considered algebraically, may be integral, considered arithmetically and *vice versâ*. For instance if $a = \frac{2}{3}$ and $b = \frac{1}{6}$, then $\frac{b}{a} = \frac{2}{3} \div \frac{1}{6} = 4$; and $a b = \frac{2}{3} \times \frac{1}{6} = \frac{1}{9}$. When therefore we speak of the fractional and integral quantities, we mean only that the symbols have these forms.

The following are examples of the application of the foregoing rule :—

Dividend.	Divisor.	Quotient.	Dividend.	Divisor.	Quotient
$2abbdd$	$2abcdd$	$\frac{b}{c}$	$21ppqq$	$42mnpq$	$\frac{pq}{2mn}$
$12axxyy$	$6aaxyz$	$\frac{2xy}{az}$	$amnxx$	$2amnxxy$	$\frac{1}{2y}$
$15abcd$	$10aadd$	$\frac{3bc}{2ad}$	$63abcd$	$7aacdd$	$\frac{9bc}{ad}$
$5anppq$	$10ampqq$	$\frac{np}{2mq}$	$12avvxx$	$8avyxxy$	$\frac{3v}{2y}$

27. Let it now be required to divide $m a - m b + m$ by m; that is, to find the quantity which multiplied into m, gives $m a - m b + m$. Now, we know from (Art. 14, p. 162), that $m (a - b + 1) = m a - m b + m$; consequently $a - b + 1$ is the quantity sought. But $a - b + 1$ is the expression $m a - m b + m$ with the common factor m struck out of every term. Therefore adopting the fractional notation, we have

$$\frac{m a - m b + m}{m} = \frac{m a}{m} - \frac{m b}{m} + \frac{m}{m} = a - o + 1.$$

In this example the symbols employed are general, and therefore we conclude that the rule for the division of a compound expression by a quantity of one term is as follows: Divide every term of the dividend by the divisor (as before) and connect the partial quotients by their proper signs as in the analogous case of multiplication (Art. 14, p. 162). The following are instances in which the division can be effected without introducing fractions into the quotient.

Dividend.	Divisor.	Quotient.
$27abb + 3abx - 12aab$	$3ab$	$9b + x - 4a$
$12aab - 16abc - 4ab$	$4ab$	$3a - 4c - 1$
$7axxy - 14xxxy + 7\, xxyz$	$7xxy$	$a - 2\, x + z$
$3am - 6aamm - amn$	$3am$	$1 - 2\, am - \frac{1}{3}n$
$12abbc - 32\, bcxx - 4abcy$	$4bc$	$3ab - 8xx - ay$

28. If the terms of the dividend are not severally divisible by the given divisor, we must treat them as directed in Art. 26. For instance, $ax + by - cz$ divided by xyz is,

$$\frac{ax + by - cz}{xyz} \text{ or } \frac{ax}{xyz} + \frac{by}{xyz} - \frac{c\,z}{xyz} \text{ or } \frac{a}{yz} + \frac{b}{xz} - \frac{c}{xy}$$

The division here is not completed, but only reduced to a series of more simple divisions. The following are instances of the same kind.

$$\frac{aabb + 4aab}{aabb} = 1 + \frac{4}{b} \qquad \frac{a + b + c}{abc} = \frac{1}{bc} + \frac{1}{ac} + \frac{1}{ab}$$

$$\frac{3abc - 6bcd}{3abcd} = \frac{1}{d} + \frac{2}{a} \qquad \frac{xx + yy + 1}{xy} = \frac{x}{y} + \frac{y}{x} + \frac{1}{xy}$$

$$\frac{3axxx - 6aaxx + 6aaax - 3aaaa}{6aaxx} = \frac{x}{2a} - 1 + \frac{a}{x} - \frac{aa}{2xx}$$

$$\frac{4a + 4b - 3c + 2cd + 5dd}{2abcd} = \frac{2}{bcd} + \frac{2}{acd} - \frac{3}{2abd} + \frac{1}{ab} + \frac{5d}{2abc}$$

$$\frac{21ax + 7aaxy + 14xxy + 35axyz}{7axyz} = \frac{3}{yx} + \frac{a}{z} + \frac{2x}{az} + 5$$

$$\frac{ab + bc + cd}{abcd} = \frac{1}{cd} + \frac{1}{ad} + \frac{1}{ab} \qquad \frac{a - 1}{aa} = \frac{1}{a} - \frac{1}{aa}$$

$$\frac{xx + 4xy - yy}{4xxy} = \frac{1}{4y} + \frac{1}{x} - \frac{y}{4xx} \qquad \frac{a - aa}{aa} = \frac{1}{a} - 1$$

29. We have hitherto considered only the obvious cases of division; but there still remains the more complicated case requiring the division of one compound expression by another: for instance, the division of $aa - 2ab + bb$ by $a - b$. The principle of this operation is the same as that already established in the preceding cases; but a rigid investigation of it in this place would lead us into modes of reasoning for which the student is not yet prepared. Fortunately we shall stand in little need of operations of this sort for some time, except in their simplest forms, and which may in general be effected by a knowledge of the theorems of multiplication. The rule for the process may however be loosely established in this way: taking the example written above, we observe that the first term aa of the dividend $aa - 2ab + bb$ contains a, the first term of the divisor a times; we therefore conclude that a times $(a - b)$, that is, $aa - ab$ must be a part of the dividend. Let that part be subtracted; that is, let

$$(aa - 2ab + bb) - (aa - ab) = -ab + bb$$

Now the first term of this remainder again contains a, the first term of the divisor, b times; we therefore conclude that b is another term of the quotient, and as ab has the negative sign, we further conclude from the rules for the signs in multiplication, that b ought also to be preceded by this sign: hence b times $(a - b)$, that is $ab - bb$ with all its signs changed (because b has the subtractive sign $-$), ought to be a part (in this case the whole) of the remainder $-ab + bb$; that is,

$$(-ab + bb) - (-b)(a - b) \text{ or } -(-ab + bb) = 0$$

As we have now nothing remaining, we conclude that $a - b$ is the quotient; in other words, that the given dividend $aa - 2ab + bb$ is the square or second power of the given divisor $a - b$.

This process is in every respect analogous to "long division," in arithmetic, and is commonly written in the same manner; thus—

$$\begin{array}{l|l}
 & \text{Divisor.} \quad \text{Dividend.} \quad \text{Quotient.} \\
 & a - b)\ aa - 2ab + bb\ (a - b \\
\dfrac{aa}{a} = a & \qquad\quad \underline{aa - ab} \\
 & \qquad\qquad - ab + bb = \text{first Rem.} \\
\dfrac{-ab}{a} = -b & \qquad\qquad \underline{- ab + bb} \\
 & \qquad\qquad\qquad 0 \quad = \text{second Rem.}
\end{array}$$

The rule is therefore this: Having arranged the terms according to the powers of some one letter, in this case according to the powers of a, we inquire how often the first term of the divisor is contained in the first term of the dividend; that is, how often a is contained in $a\,a$, and write down the result a, as the first term of the quotient; we multiply the whole of the divisor by that term, and subtract the product, namely $a\,a - a\,b$ from the dividend, and write down the remainder of the dividend, (or as many terms of it as the case may require), and repeat the operation till all the terms of the dividend are exhausted. The whole dividend is thus in reality divided into so many parts by the process, each of which contains the product of the divisor and a simple factor.

30. The divisor and dividend must be arranged, as already stated, according to the powers of some one letter (either ascending or descending) otherwise the quotient will not be found in its simplest form, and possibly the division will not be effected in finite terms. Let us as an illustration change the order of the example given above, thus:—

$$\begin{array}{l|l}
-b + a)\ b\,b - 2\,b\,a + a\,a\ (-b + a & \\
\qquad\quad \underline{+ b\,b - b\,a} & \dfrac{+b\,b}{-b} = -b \\
\qquad\quad - b\,a + a\,a & \\
\qquad\quad \underline{- b\,a + a\,a} & \dfrac{-b\,a}{-b} = +a
\end{array}$$

Here we observe that the operation is in effect the same as before, but it illustrates another fact with regard to the signs, namely, that $b\,b$ being divided by $-b$ gives for quotient $-b$ and that $-b\,a$ divided by $-b$ gives for quotient $+a$; that is, the signs of the dividend and divisor being alike, the sign of the quotient is $+$; and the signs of the dividend and divisor being different, the sign of the quotient is $-$. This it will be remembered is the same rule which we found to obtain in multiplication. (Art. 15, p. 162.)

31. Again, let the terms of our example be written down without attention to the order of the letters, and apply the rule thus:—

$$\begin{array}{l}
a - b)\ -2\,a\,b + a\,a + b\,b\ (-2\,b + a + b \\
\qquad\quad \underline{-2\,a\,b \qquad\quad + 2bb} \\
\qquad\qquad\quad a\,a - b\,b \\
\qquad\qquad\quad \underline{a\,a - a\,b} \\
\qquad\qquad\qquad a\,b - b\,b \\
\qquad\qquad\qquad \underline{a\,b - b\,b}
\end{array}$$

But we know that this quotient $-2\,b + a + b = a - b$: The process is therefore correct as before, but less simple. By a further derangement of the terms, we may render it impossible, abiding strictly by the rule, to effect the division at all. Thus by taking the divisor $a - b$ and arranging the dividend in the order $b\,b + a\,a - 2\,a\,b$ we get for quotient

$$\frac{b\,b}{a} + a + \frac{b\,b\,b}{a\,a} - \frac{b\,b\,b\,b}{a\,a\,a} - \frac{b\,b\,b\,b\,b}{a\,a\,a\,a} - \&c.$$

32. Should it be found that a division cannot be effected, the quotient will be completed at any term by adding to the terms found, a term formed by writing the remainder over the divisor in the form of a fraction,

$$\text{Thus, } \frac{a\,a + 4\,a\,b + 4\,b\,b + c}{a + 2\,b} = a + 2\,b + \frac{c}{a + 2\,b}$$

which the student may verify by actual division according to the method illustrated by the previous example.

He may also verify the following by the rule, namely,

$$\frac{a\,a\,a - b\,b}{a - b} = a\,a + a\,b + b$$

$$\frac{a\,a\,a\,a - 2\,a\,a\,b\,b + b\,b\,b\,b - c\,c\,c\,c}{a\,a + b\,b + c\,c} = aa + bb - cc$$

$$\frac{y\,y\,y - 1}{y - 1} = y\,y + y + 1$$

$$\frac{1}{1 - x} = 1 + x + x\,x + x\,x\,x + x\,x\,x\,x + \frac{x\,x\,x\,x\,x}{1 - x}$$

Such instances as the following, which are of the most frequent occurrence, should be done at sight:—

$$\frac{6\,a\,a - 9\,a\,x}{2\,a - 3\,x} = \frac{3\,a\,(2\,a - 3\,x)}{(2\,a - 3\,x)} = 3\,a$$

$$\frac{4\,a\,b - 2\,a\,c}{6\,a\,b - 3\,a\,c} = \frac{2\,(2\,a\,b - a\,c)}{3\,(2\,a\,b - a\,c)} = \tfrac{2}{3}$$

$$\frac{a\,a - x\,x}{a + x} = \frac{(a + x)\,(a - x)}{(a + x)} = a - x$$

$$\frac{a\,a + 2\,a\,b + b\,b}{a + b} = \frac{(a + b)\,(a + b)}{(a + b)} = a + b$$

$$\frac{x\,x - 9}{x + 3} = x - 3 \qquad\qquad \frac{49 - x\,x}{7 + x} = 7 - x$$

$$\frac{(6aa + 6ab) - (8ax + 8bx) - (9\,ay + 9\,by)}{a + b} = 6a - 8x - 9y.$$

33. We shall have occasion to return hereafter to the investigation of the rule for the division of one compound expression by another; but if the fundamental principle of division be well understood, what has been here shown of the mode of conducting such operations will generally be found quite sufficient to enable the student to advance satisfactorily. He may, however, form

other examples for himself, which may readily be done by the rules of multiplication; and it would be well that he exercised himself in verifying his operations upon particular numbers; for, be it observed, if the rules be true in algebra, they must be equally true in arithmetic, and equally applicable. Thus, suppose we have such a question as

$$\frac{a a + 2 a b + b b}{a - b} = a + 3 b + \frac{4 b b}{a - b}$$

and that $a = 11$, and $b = 8$; then, by substituting these numbers for the letters in the question, we get

$$\frac{121 + 176 + 64}{11 - 8} = 11 + 24 + \frac{256}{11 - 8} \text{ or } \frac{361}{3} = 120\tfrac{1}{3}$$

Facility in verifying expressions of this nature, by converting the symbols into numbers, is of much importance, as will shortly appear, and may be obtained by moderate practice.

STATIONARY ENGINES AND GEARING AT COWLAIRS AND EDGE-HILL,

ON THE INCLINES OF THE EDINBURGH AND GLASGOW, AND LONDON AND NORTH-WESTERN RAILWAYS.

(Illustrated by Five Plates.)

THE systems of machinery adopted for drawing up the trains on the two important inclines at Liverpool and Glasgow—the former on the London and North-Western, and the latter on the Edinburgh and Glasgow Railway—are similar in the apparatus employed. We have therefore selected, for our illustrations of the principle and mode of working in each, that in which the average gradient is highest, the incline longest, and consequently the power employed greatest. The incline at Glasgow is $1\frac{1}{2}$ miles in length, and the average gradient is 1 in 44; while the length of the tunnel at Liverpool is 50 yards short of a mile, and the gradient is only 1 in 80.

The Glasgow and Cowlairs incline commences at the entrance to the tunnel at the Glasgow terminus, and terminates at Cowlairs station, where the engines, and consequently the main part of the gearing, are situated. The trains are drawn up the incline by an endless wire rope, which is carried upon guide-pulleys, as will subsequently be noticed, at a rate usually of 12 miles an hour, which is the slow motion; when the train is light, this rate may, however, be increased to 20 miles an hour. Communication is maintained between the Cowlairs station and the foot of the incline, by means of an electric telegraph of Cooke and Wheatstone's construction.

ENGINES AND GEARING ON THE LIVERPOOL INCLINE.

The Lime Street tunnel at Liverpool was opened for traffic on the 15th August, 1836. It is worked by a pair of engines (two cylinders) of the collective nominal power of 80 horses, while, as we shall afterwards see, the combined power of the engines at Cowlairs, near Glasgow, is upwards of 200 horse power. The driving-wheel propelled by the engines at Edge-hill is 19 feet diameter, and round this traverses an endless hempen rope, $8\frac{1}{2}$ inches in circumference. This rope is carried down and up the tunnel on cast-iron pulleys, 20 inches diameter, and the trains are attached to it by light messenger-ropes. The length of the tunnel, as already stated, is about 50 yards less than a mile, and the gradient 1 in 80. The rope is only used to convey trains *up* the incline. The time taken in bringing up an express train, say of six carriages, averages five minutes; to bring up an ordinary train, five and a half or six minutes are required —the time varying very little on account of the weight. Cooke and Wheatstone's telegraph is used here also.

ENGINES AND GEARING IN THE ENGINE-HOUSE AT COWLAIRS, NEAR GLASGOW.

(Plates I., II., and III.)

PLATE I.—This plate contains an elevation of both the engines at Cowlairs, taken at an angle of forty-five degrees to the vertical planes of position—the eye, as in other mechanical drawings, being supposed at an infinite distance. The representation is therefore equally made an end and side elevation, being equidistant from the planes of both. The scale of the drawing is *three-eighths* of an inch to a foot (that is, $\frac{1}{32}$ of the full size), and may be applied directly to all the vertical lines and rounds; but for horizontal lines the scale must be reduced to $\frac{1}{4}$ inch (more nearly 0·265 inch).

The engines, it will be perceived, belong to the high-pressure class. The steam cylinders are each 28 inches diameter, with 6 feet of stroke. They are supplied with steam by eight boilers, each 30 feet long by 5 feet diameter, with a flue of $20\frac{1}{2}$ inches diameter. The general pressure in the boilers is 50 lbs. on the square inch; and the number of strokes of each engine per minute 19, so that the combined power, calculated by Tredgold's rule, is 205 H.P.

The drawing shows the working beams and spring beams, supported upon a strong entablature, which rests upon four fluted columns, set on pedestals. The entablatures, columns, and pedestals, are all of cast-iron; the columns are turned at their upper ends, and accurately fitted and cottered into sockets bored in the entablature, as shown in fig. 1 of Plate IV., upon which all the principal dimensions are marked. All the centres in the beams are likewise fitted metal-and-metal, by boring and turning, and both the beams and the connecting-rods are turned and polished at their extremities, and feather-edged throughout their length. The details of the connecting-rods, with the dimensions marked, are given in fig. 2 of Plate IV. The construction of the links of the parallel motion is shown also in the same plate, in full detail, fig. 3. These, of course, and the cranks and crank-shaft, are of malleable iron.

On the crank-shaft is placed a large spur-wheel of 12 feet diameter, 4 inches pitch, 15 inches breadth, and weighing eleven and a half tons. This wheel, which is shown in proportion and position in the drawing, communicates its motion, by a pinion of 6 feet 7 inches diameter, to the pulley gearing, by which the traction rope of the incline is worked, and which will subsequently be described. The other parts of the engines are more distinctly shown in the drawings of the two other plates.

PLATE II.—This gives a front view of the cylinders and nozzles, and shows the steam-pipes and valve-gearing, on a scale of one-fourth of an inch to the foot, or 1-48th.

PLATE III.—This exhibits the engines in plan. In the one engine, the beam, spring beams, and entablature are removed, and the cylinder, nozzle columns, and main columns are shown in section, also on a scale of one-fourth of an inch to the foot, or 1-48th.

The steam-pipe, *a a*, from the boilers, is fitted with stop-valves at the branches, *b b*, of the nozzles. These valves are opened and shut by a shaft communicating from the wheel, *c*, at the hand of the engineer.

The nozzles are cast in one piece, and fitted with piston-valves working in two cylinders, as shown in elevation in the main figure, and also separately by *d d* in the section, by the figure marked No. 1 in Plate II. The figure marked No. 2, in the same plate, shows the nozzles in plan. The ports or steam passages from the valve-cylinders are formed by oblong openings, placed diagonally in the periphery of the cylinders, to prevent any unequal wear of the pistons. The pistons of the valves are worked from the wyper-shafts, *e e*, by the levers connected to the hollow stuffing-boxes, *f f*, attached to the piston-rods.

The starting-bars, *g g*, of both engines, are placed at the side of the engine-house, near the wheel for the steam-valve, so that the engineer, when working the engines, may be able to see down the incline from one of the engine-house windows.

The wyper-shaft of the near engine is hollow, to allow the shaft of the far engine to pass through it. The cylinders and nozzles are joined by planed faces, metal-to-metal.

The waste steam from the steam-cylinders is blown into a heating-chest by the exhaust pipes, *h h*. This chest is filled with shelves, leaving a space alternately at the ends of the shelves for the passage of the steam and the water. The construction is indicated by dotted lines in the main figure, and is also shown separately in section in Plate II. Each engine has attached to it a cold-water pump, *k k*, which draws the water from the pond, and throws it into the top of the heating-chest, and passing down through the shelving, it condenses and abstracts the heat of the waste steam. The feed-pumps, *p p*, take the heated water from the bottom of the chest to the boilers.

The boilers are placed close to the engine-house, and a range of pipes, 10 inches diameter, conveys the steam to the main steam-pipe, and thence to the nozzles. The steam-pipe of each boiler has a stop or shut valve; there are also two valves upon the main steam-pipe in the engine-house, worked by a shaft communicating to the hand of the engineer.

PULLEY GEARING FOR WORKING ENDLESS ROPE.

(Plates IV., V.—Scale one-fourth inch to the foot.)

As already stated, the power of the engines is transmitted to the pulley gearing for working the endless rope, by the large spur-wheel upon the intermediate or crank-shaft of the engines. This wheel, A, works into a pinion, B, of 6 feet 7 inches diameter on a first motion shaft, and likewise into another pinion of the same size on a

STATIONARY ENGINES AT COWLAIRS ON THE INCLINE OF THE EDINBURGH & GLASGOW RAILWAY.

Messrs. Neilson & Mitchell Hyde Park Foundry Glasgow

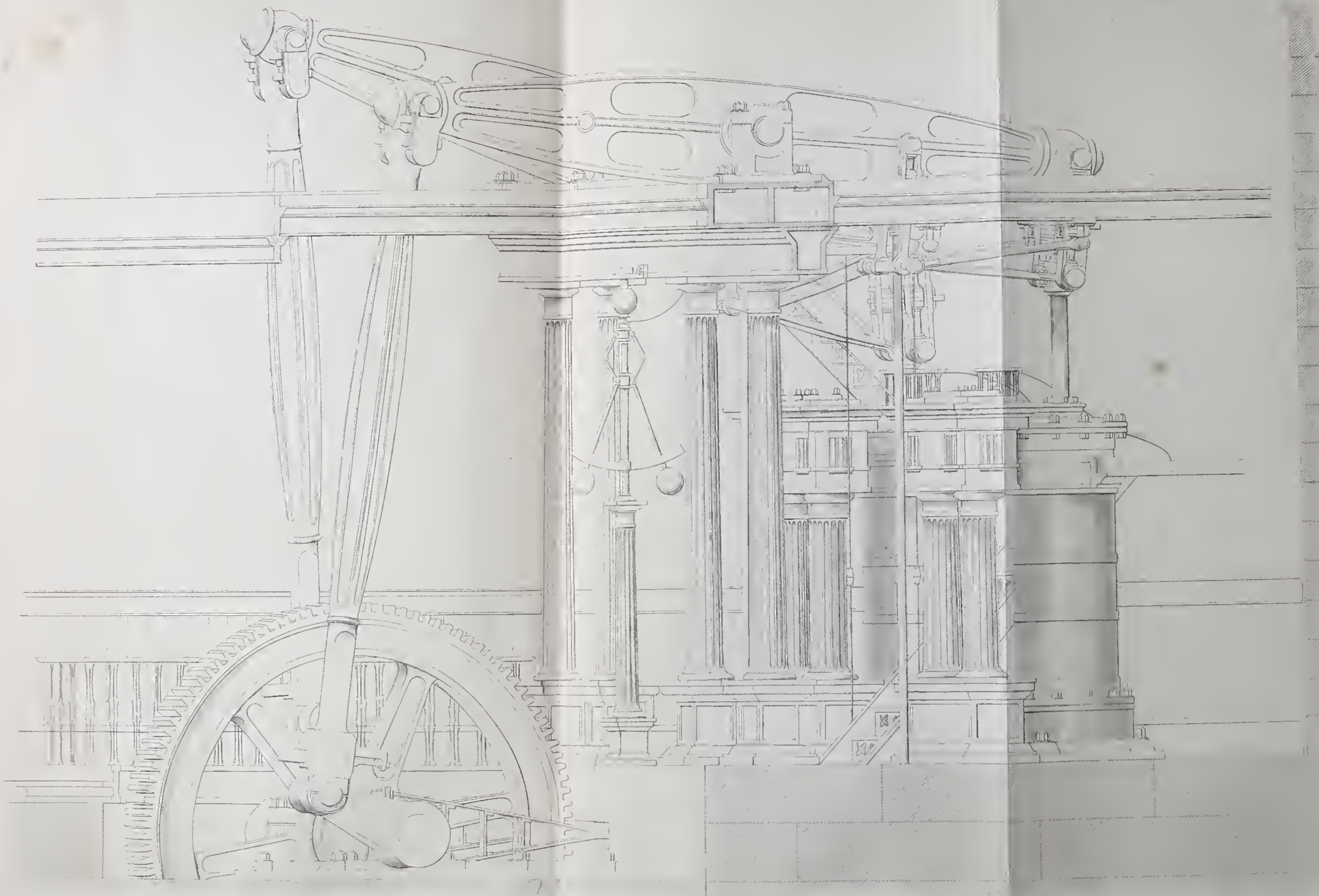


PLATE II.

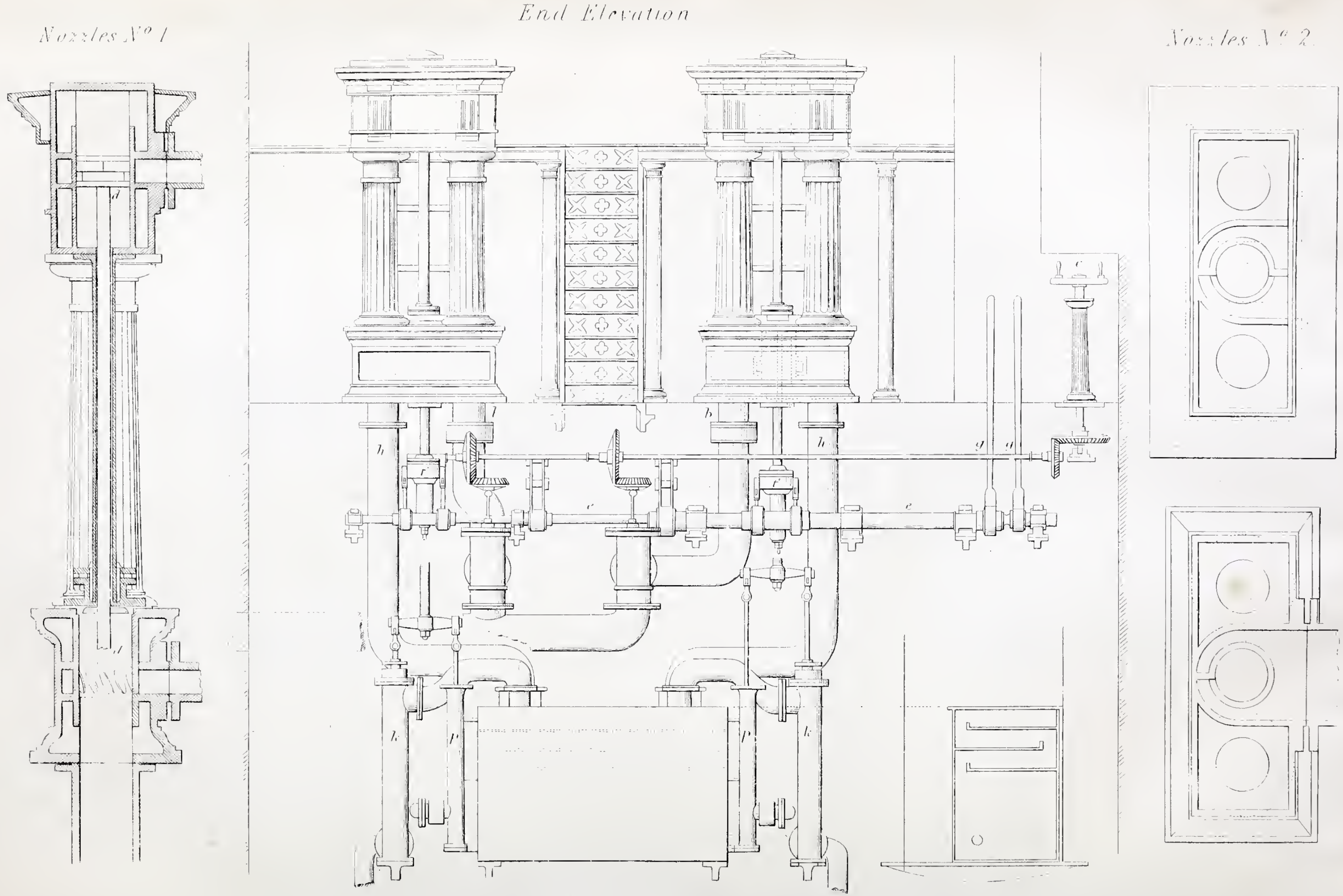
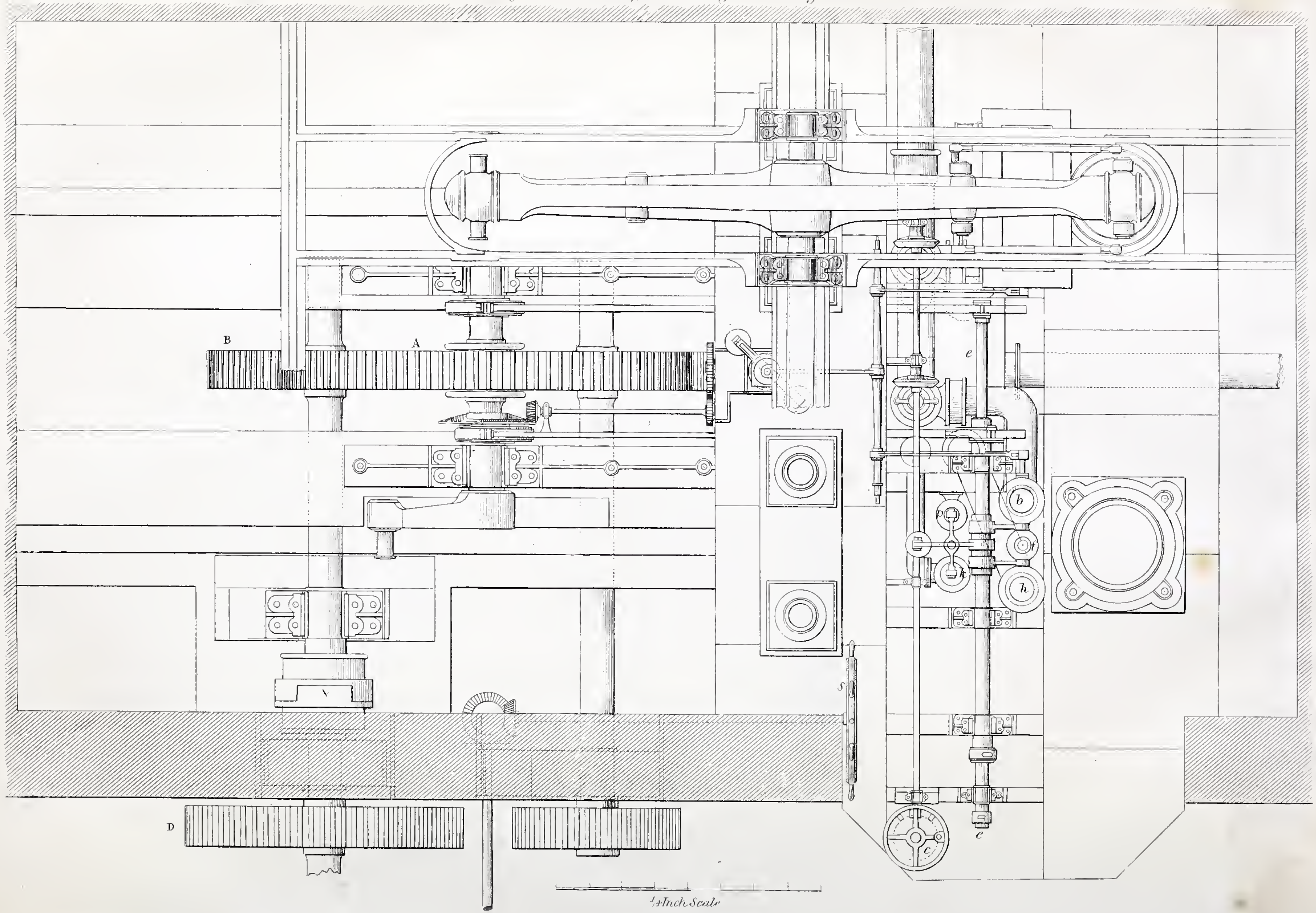


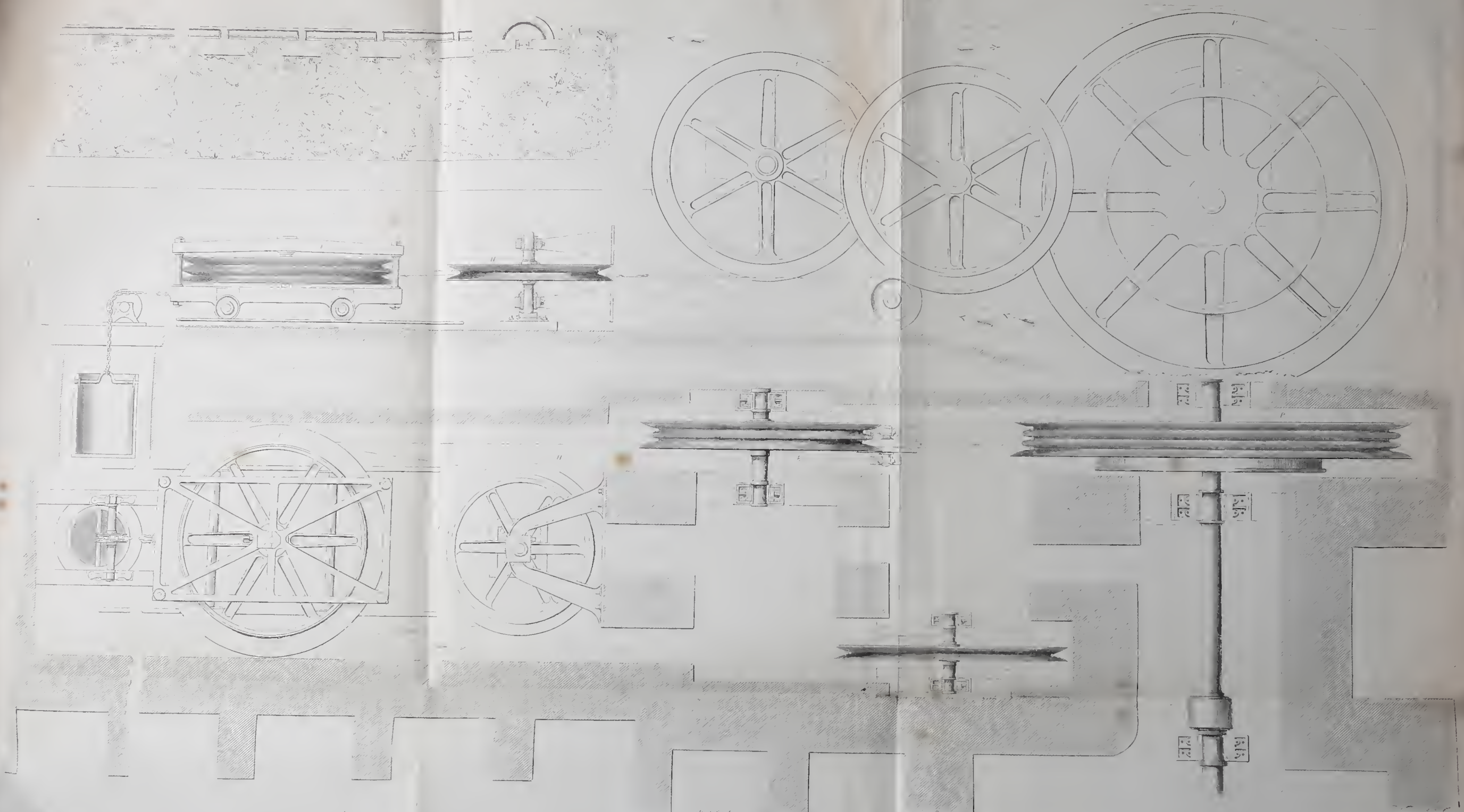
PLATE III

Plan of Engines & Heavy Geering in Engine House.



SYSTEM OF WORKING INCLINES AS APPLIED AT THE EDGEHILL STATION, LIVERPOOL & COWLAIRS, GLASGOW.

PULLEY GEARING FOR ENDLESS ROPE ON THE INCLINE



second motion shaft. This last is not seen in fig. 4 of Plate IV., but is shown in the plan of the engines, Plate III. These shafts are connected by two pinions of different sizes, in order to obtain two speeds on the line; the pinion, D, on the first motion shaft, is 8 feet diameter, and that on the second motion shaft, 5 feet diameter. The main wheel, A, on the crank-shaft, can be geared into either of the first pinions, B, at pleasure, according as the slow or quick speed is desirable—the quick speed being had when the pinion, B, upon the first motion shaft is in gear, and the slow speed when the corresponding pulley upon the second motion shaft is in gear.

For the purpose of effecting this change of speed, the first motion shaft is provided with a strong clutch-coupling, V, and both shafts set upon sliding pillow-blocks, *t t*. To change from the quick to the slow speed, the moveable half of the coupling, V, is slid back upon its shaft; the moveable pillow-blocks are then taken back to bring the pinion out of gear with the main wheel, A; the pillow-blocks of the second motion shaft are then shifted forward, till its first pinion, B, is brought into gear with the main wheel, A, and its second, or 5-feet pinion, into gear with the 8-feet pinion, D, which is fast upon the main pulley-shaft: the operation is then complete. The arrangement is shown very clearly in the plan, Plate II., and by fig. 4 of Plate IV.

The main pulley, P, which is placed under the line of rails as shown in the elevation, Plate V., is 18 feet diameter, has three grooves for the rope in its periphery, and weighs 27 tons. It is fitted accurately together in eight arms, and an equal number of segments, to a centre, as shown by fig. 5 in Plate IV. It carries a drag race, *v*, strongly bolted to the arms, through which, by means of its strap, the engines may be instantly stopped in case of accident. The friction-strap is of malleable iron, lined with plate copper, that it may act the more energetically, and be less liable to heat while bringing the pulley to rest. This strap is worked by a wheel, *s*, shown in Plate III.

From the main pulley, the rope passes over two 10-feet double-grooved pulleys, E and F, weighing about 10 tons each; one 10-feet single-grooved pulley, G, of about 4½ tons, and a 7-feet single-grooved pulley, H, of about 2½ tons. The pulley, F, is placed horizontally upon a carriage or frame, set upon rails, as shown in Plate V., and has a run of 20 yards. To the end of the carriage is attached a chain, which passes over a pulley at the end of the rails, and descends into a well, suspending a weight of about 4 tons as a counterbalance, and to keep the rope taut. The pulley, H, is also placed horizontally, opposite pulley, F, for the purpose of reversing the direction of the rope. All the pulley centres are of malleable iron, running in brass-bushed pillow-blocks. The main pulley-shaft is also of malleable iron, and 12 inches diameter.

The course of the rope is indicated in direction by arrows, marked both on the elevation and plan given in Plate V. On the ascending side of the line, it enters upon the main pulley, P, from which it turns to the pulley, E, forming two turns and a half upon P, and one and a half upon E. It then leads to the boggie pulley, F, making one and a half turns upon it, and half a turn upon the pulley, H, passing from pulley, F, to pulley, G, and then to the descending line, where, near the mouth of the tunnel at Queen Street, it passes round a pulley of 10 feet diameter, placed horizontally under the rails. This pulley is shown by fig. 6 in Plate IV. The rope then leads up the incline, and is supported throughout by a series of guide-pulleys set about 18 feet apart. These pulleys are built of wood upon iron centres, with malleable iron spindles passing through them, which run in brass bearings; they are set in neat cast-iron boxes, fixed in the ground between the rails.

THEORY AND PRACTICE OF DYEING.

CHAPTER VIII.

VEGETABLE DYE-STUFFS.

I. LOGWOOD.—The *Bois de Campeche* and *Bois bleu* of the French, and the *Blauholz* of the German dyers.—This wood is brought to us from Jamaica and the eastern shores of the bay of Campeachy; on this account it is distinguished in commerce by the names of *Campeachy* and *Jamaica* logwood. The former is considered much superior to the latter, and brings always a higher price in the market. Among botanists, the logwood tree is known by the name of *Hæmatoxylon Campechiacum.* In a favourable soil it grows to a very great size; its bark is thin and smooth, but is furnished with thorns; its leaves resemble the laurel; its wood is hard, compact, and capable of taking a fine polish; its specific gravity is much higher than water, in which it consequently sinks.

We are not aware who first introduced logwood as a dyeing agent; but its nature, and the art of using it as such, seems to have been but little understood in the reign of Queen Elizabeth; for we find her government issuing an enactment entirely forbidding its use. The document is curious, and affords good proof of the absurdity of a government interfering with the rights of the subject in matters of which it is ignorant. The act is entitled, "An Act for the abolishing of certeine deceitful stuffe used in dyeing of clothes;" and it goes on to state that, "Whereas there hath been brought from beyond the seas a certeine kind of stuffe called logwood, alias blockwood, wherewith divers dyers;" and "Whereas the clothes therewith dyed, are not only solde and uttered to the great deceyte of the Queenes loving subjects, but beyond the seas, to the great discredit and sclaunder of the dyers of this realme. For reformation whereof, be it enacted by the Queene our Soveraygne Ladie, that all such logwood, in whoes handes soever founde, shall be openly burned by authoritie of the maior." This act was put forth in the 23d year of the Queen's reign, and was renewed again in the 39th, with the addition, that the person so offending was liable to imprisonment and the pillory.* Upwards of eighty years elapsed before the real virtues of this dyeing agent were acknowledged; and there is no dyewood we know now so universally used, and so universally useful.

Like many other valuable substances, logwood was long used before anything was known of the real nature of the colouring principle. Chevreul, an eminent French chemist, made a chemical examination of the wood, and found it to contain a distinct colouring substance, which he called hæmatine, a name which has since been changed to hæmatoxylin, to avoid any confusion with the hæmatin of the blood. Logwood contains, besides this colouring matter, resin and oil, acetic acid, and a double salt of potash and lime with a vegetable acid. It sometimes contains also sulphate of lime, a little alumina, peroxide of iron, and oxide of manganese. These ingredients, however, vary; some woods having more than others, and others wanting some of the ingredients altogether. This variousness of constitution, no doubt, arises from the varying qualities of the soil on which the wood is grown; but the quantity of some of the mineral ingredients has frequently a baneful effect upon light shades, giving to the dye a great tendency to darken, or in dyers' language, to *sadden* the colour,

Chevreul's process for procuring the colouring matter is, by subjecting logwood, after grinding, to digestion, for a few hours in water at 120° or 130° Fahr., afterwards filtering the liquor and evaporating to dryness; what remains is put into strong alcohol for a day; this is again filtered, and the clear liquor evaporated till it becomes thick; to this is added a little water and evaporated anew; it is then left to itself, and the colouring matter crystallizes.

An improvement on this method has been recommended by Erdmann. The extract of logwood, being evaporated to dryness, is pulverized and mixed with a considerable quantity of pure silicious sand, to prevent the agglutination of the extract, and the whole allowed to stand several days with five or six times its volume of ether; the mixture being often shaken, the clear solution is poured off and distilled until there is only a small syrupy residue. By this means most of the ether is saved; and this being mixed with a certain quantity of water, is allowed to stand for some days, when the hæmatoxylin crystallizes out and may be dried between folds of blotting paper.

We are afraid both of these processes will be too tedious for adoption in a dyehouse. We have seen some very good specimens of the hæmatoxylin obtained by evaporating a strong decoction of logwood nearly to dryness, and allowing it to stand for several days; a solid matter settles to the bottom, having a syrupy fluid above it; large crystals of hæmatoxylin appear to grow from the crust, giving it, when removed, a most beautiful velvety appearance. The crystals vary in length from ¼th to ⅝ths of an inch. They dissolve readily in hot water, but very slowly

* It should be remarked, in extenuation of this ungracious interference, that the dyers of the good Queen's time were incapable of producing any fast colour with logwood; and therefore, presuming that only fugitive colours could be produced by its use, for the honour and credit of the Queen's most loving subjects forbade the use of the pernicious stuff.—ED.

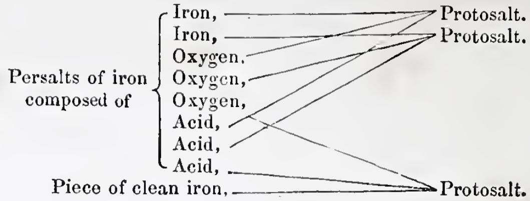
in cold; the matter is also soluble in alcohol. When dissolved in distilled water, the solution has a beautiful rich wine colour; but, when the least trace of lime or iron is present in the water, (and very few waters are free of these) its colour is materially altered. The action of reagents is very powerful. Potash, when first put in, colours the solution violet; but this speedily passes into a purple, becoming brownish-yellow; and, in a little time, the mixture becomes almost colourless. The reason of this final change is, that a quantity of oxygen is absorbed; the hæmatoxylin is thereby destroyed, and the caustic alkali converted into a carbonate from the decomposition of the colouring matter. Caustic soda has a similar effect; but the carbonate of soda is much more mild in its action than carbonate of potash.

The action of ammonia on hæmatoxylin is similar to that of potash and soda, but much more powerful in regard to its changing colour, and less destructive upon the substance. Some beautiful and also amusing experiments may be performed with ammonia and the colouring matter of logwood. If a jar full of distilled water be taken, and a few drops of a solution of hæmatoxylin be added, not so much as to give a perceptible colouring to the water; on adding a few drops of ammonia, the water instantly takes a reddish tint, and changes so rapidly, that in two minutes, if the jar is large, the colour is so dark a violet shade, that the light can hardly be transmitted; in a little it becomes redder, and gradually passes away. This experiment may be repeated by placing the jar simply in the fumes of ammonia; the water begins to colour at the top, and as the absorption goes on, the colour passes gradually down, so that when it is dark at the top it is slightly tinged at the bottom, and so on till the whole is converted into a dark violet seemingly by magic.

Erdmann has been able to collect this compound of hematoxylin and ammonia, and finds that the colouring matter absorbs three equivalents of oxygen under the influence of the ammonia, and is converted into a substance which he names *hæmatein*. This hæmatein combines with ammonia and forms a violet black powder which is soluble in water, giving it an intense purple colour, which spontaneously fades and passes away by keeping.

The action of the alkalis upon logwood is similar to those described upon its colouring matter, and suggests the cause why those who add a little alkali to their logwood liquor while dyeing black, on purpose to give the colour of the logwood a richness, and prevent the action of the iron upon it, invariably have a gray bad black. Stale urine, indeed, which is most generally used for this purpose, if not used cautiously, produces the same bad colour, from the ammonia which it contains. For this reason also, when lime is used to pass the cloth through, after being impregnated with iron, we always wash from the lime, otherwise the lime on the cloth causes the colouring matter to undergo similar changes with the other alkaline substances, and gives the blacks thus dyed a grayish appearance.

The action of metallic oxides upon the colouring matter of logwood is somewhat similar to the action of these oxides on logwood itself, varying considerably with the dissolving menstrua of the oxide and the particular state of oxidation. Thus protosalts of iron give a blue-black; permanent persalts of iron, a jet black, becoming brown; neutral protosalts of tin, a rich wine colour; permanent persalts of tin, a deep wine colour, becoming brownish; acetate of lead a brownish-black, becoming bluish; acetate of copper, a greenish-black, becoming brownish.—These are the principal metallic salts used with logwood and their effects. The acid in which the oxides are dissolved affects materially the results obtained; the iron is used as the sulphates or acetates; the tin as chlorides; lead and copper as acetates. The protosalts give, with logwood, the most brilliant, and also the most permanent colours. The iron protosalts, if exposed to the air, pass very readily into the state of persalts, especially if the salts be neutral—that is, have no more acid than is combined with the oxide. A little free acid prevents this change, but generally produces bad effects. However, where the use of a protosalt of iron is necessary, any persalt in the mordant may be reduced to the proto-state by the immersion in it of a piece of clean iron, a few hours previous to using the solution. When an iron salt becomes peroxidized by exposure to the air, every third atom is precipitated as an insoluble oxide —the acid leaving this atom, and combining with two atoms iron, and three oxygen, to form a persalt, which is composed of three acid, three oxygen, and two iron. When a piece of iron is put into a persalt solution, the following reaction takes place:—



This operation ought to be performed just previous to using, and as little exposed as possible; for when the salt is all converted into the proto-state, the atmosphere again speedily destroys it.

Decoctions of logwood are prepared in the dyehouse, either by boiling or *scalding;* if the logwood be chipped or cut, it requires to be boiled for two or three hours. This generally gives the purest and finest colours for *plumb-tubs.* When the wood is ground, the decoctions are generally made by pouring boiling water upon it. Some put the quantity required into a tub; fill this with boiling water; allow the grounds to settle, and decant the solution; but the best method is to use a basket, lined with cloth;—the logwood is put into the basket, and boiling water poured upon it; the clean decoction filters through. No more logwood should be taken than what is to be used at the time, as it loses its dyeing properties by standing; the colour passes from a rich wine-hue to a yellow-brown; and assumes a syrupy appearance; and colours dyed by it after this change takes place, are always wanting in brilliancy—they, besides, take a greater quantity to produce the same depth of shade.

Parkes, in his chemical essays, has the following observations bearing upon this subject:—"Considerable advantage is derived by the woollen dyers from the use of water in the preparation of rasped logwood. As the wood is cut into chips, they sprinkle it abundantly with water, and in that moistened state it is thrown into large heaps, and sometimes into bins of great size, where it is suffered to lie as long as is convenient. By this treatment, the chips become heated, or they ferment, as the dyers call it, and thus undergo a very remarkable change; for, after having lain a few months in this state, they give out the colouring matter in the dyeing copper much more easily; and any given quantity of such chip will produce a more intense dye than could have been obtained from an equal quantity of chips which had not been thus heated. It is difficult to account for this, unless we suppose that the water becomes in part decomposed, and that its oxygen, uniting with the vegetable colouring matter, renders it more intense." We have found that, by damping the wood with boiling water a little before pouring the necessary quantity of boiling water upon it, the wood, in the language of the dyer, is much better *bled;* but we considered this to result from softening the particles of wood, making the colouring matter more easily dissolved by the water afterwards applied. Whether anything more is effected by the practice noticed by Mr Parkes, or if any decomposition takes place, we cannot say. If, by fermentation, is meant the formation of acids, we know that acids do not produce the effects stated; but if it is a fermentation, caused by the decomposition of any substance having nitrogen as a constituent, the result would be the formation of ammonia, a substance, as we have already noticed, which has a powerful influence upon the colouring matter of logwood, and extracts it very rapidly—a property possessed, indeed, by all alkalis and alkaline earths. This is well known to dealers in logwood, who occasionally sprinkle it with water containing a little lime, which gives the wood a richness in colour, so that the poorest woods thus *doctored*, appear equal to those of the finest quality. Such wood, however, never produces good light shades, neither does that coming through the operation of fermentation. The presence of an alkali may be detected in logwood, by taking a little in a tumbler, and allowing it to steep for a few hours in distilled water, and then trying the solution with delicate test papers.

The means we have usually adopted for testing the quality of the logwood to be purchased, were by comparing results. The samples to be tried were put into a stove to dry; then half an ounce of each was carefully weighed and put into separate jars, and an equal quantity of boiling water poured upon them; a measured quantity of each was taken, and an equal weight of cotton dyed. Having always by us some of the best samples, we were enabled to tell pretty accurately the value of the article

and seldom had to complain that we had been disappointed in the one selected.

We noticed in a former paper that, if a logwood decoction be quite cold, protochloride of tin does not precipitate it, but forms a compound of a beautifully wine-coloured solution ; but if the logwood be the least warm, it is precipitated of a deep purple or puce colour. To account for this, we may also mention that, if protochloride of tin be added to hot water, a good deal of the tin is precipitated ; the chloride of tin is decomposed, and there is formed a compound of oxide and chloride of tin which is insoluble, forming the precipitate. This decomposition sometimes takes place if the chloride of tin be neutral and added to cold water. This can be prevented by the addition of a little muriatic acid to the salts of tin, but it cannot be done with that which is to be mixed with logwood without deteriorating the mixture. This decomposition of the chloride of tin, is, we think, the cause of the logwood being precipitated, if warm, by the addition of the tin ; and the mixture of oxide and chloride formed has a very strong attraction for logwood. The decomposition and combination with the logwood is simultaneous, forming an insoluble compound, very different from that of the soluble chloride and logwood (formed when the logwood is cold) constituting the plumb tub.

It is this property of the decomposition of the salts of tin, when diluted with water, which renders it so desirable as a mordant. We formerly mentioned the chloride of tin as a mordant for logwood, the goods being put through the solution, and afterwards well washed. Were this salt of tin remaining soluble when the goods were washed, the mordant would be dissolved from the cloth ; but the chloride of tin in the cloth is decomposed during the operation of washing, and there remains fixed in the fibres the insoluble compound of tin, constituting a mordant which combines easily with the logwood. Probably the cloth itself acts a part in assisting this decomposition, which would account for the cloth being dyed permanently by immersions into a soluble compound of tin and logwood, as noticed in a former paper in reference to plumb tubs ; but the various compositions of tin and logwood have not yet been studied chemically.

II. Brazil Wood.—The *Bois de Pernambouc* of the French, and the *Brasilienholz* of the German dyer. There are several varieties of this wood, generally named after the places from which they are brought, such as Pernambuca, Japan, &c. They are known amongst dyers by the general name of *Peach wood*, from an inferior kind which is often used, and which is brought from Campeachy. The following paragraph upon these woods is taken from Bell's Geography. "The *ibiripitanga*, or Brazil wood, called in Pernambuco, the *pao da rainha* (Queen's wood), on account of its being a government monopoly, is now rarely to be seen within many leagues of the coast, owing to the improvident manner in which it has been cut down by the government agents, without any regard being paid to the size of the tree or to its cultivation. It is not a lofty tree. At a short distance from the ground, innumerable branches spring forth, and extend in every direction in a straggling, irregular, and unpleasing manner. The leaves are small and not luxuriant ; the wood is very hard and heavy, takes a high polish, and sinks in water ; the only valuable portion of it is the heart, as the outward coat of wood has not any peculiarity. The name of this wood is derived from *brasas*, a glowing fire or coal—its botanical name is *Cæsalpinia brasileto*. The leaves are pinnated ; the flowers white and papilionaceous, growing in a pyramidal spike ; one species has flowers variegated with red. The branches are slender, and full of small prickles. There are nine species."

Camwood may be ranked with the Brazil woods, as it possesses similar dyeing properties. It is imported from Sierra Leone, and is very extensively used in the dyehouse.

The history of the introduction of these woods into this country is somewhat obscure ; but being mostly from the New World, it may be inferred that they were not known in this country before the beginning of the 16th century.

Brazil wood possesses like logwood a distinct colouring matter of a fine red colour. Chevreul gives the following process for extracting it in a state of purity :—" Digest the raspings of the wood in water till all the colouring matter is dissolved, and evaporate the infusion to dryness to get rid of a little acetic acid which it contains. Dissolve the residue in water, and agitate the solution with litharge to get rid of a little fixed acid which it contains. Evaporate again to dryness, digest the residue in alcohol, filter and evaporate to drive off the alcohol. Dilute the residual matter with water, and add to the liquid a solution of glue, till all the tannin which it contains is thrown down ; filter again and evaporate to dryness, and digest the residue in alcohol, which will leave undissolved any excess of glue which may have been added. This last alcoholic solution being evaporated to dryness, leaves *brezilin*, the colouring matter of the wood, in a state of considerable purity."

Brezilin is very soluble both in water and alcohol, but from the hardness of the wood the colouring matter is not completely extracted except by boiling ; even the method recommended for logwood does not dissolve all the brezilin. The decoction when boiled has a deep red colour, but passes into a rich yellow red by standing. Acids give this solution a yellowish colour, but render it unfit for dyeing operations. Alkalis communicate a violet colour which is very fugitive.

Protosulphate of iron.—Dark purple, not changed by standing.
Persulphate of iron.—Blackish brown, permanent.
Chloride of tin.—Changes to a deep crimson.
Do. with warmed liquor, a deep red precipitate.
Acetate of copper.—Dark purple.

The nitrates of the metals almost all destroy the red colour of Brazil wood, turning it into a dirty yellow. The salts of potash, soda, and ammonia, change the decoction into a rose colour, which soon passes away by standing. Alum throws down a bulky red precipitate. This substance, and the chloride of tin, are considered the proper mordants for Brazil wood ; but all the colours obtained by this wood are exceedingly fugitive, losing their brilliancy on a short exposure to air. The sun has a very powerful influence upon colours dyed by this wood. By a short exposure, the red colour assumes a blackish tint, passes into a brown, and fades away into a light dun colour. These changes are supposed to be from the colouring matter being decomposed into water or some other volatile substance, leaving a part of the carbon free, which produces the black ; but heat is also very destructive to this colour; nevertheless, the consumpt of Brazil wood is very great, especially for dyeing what is termed fancy reds.

Though Cam wood may be ranked amongst the Brazil woods, being used in the dyehouse for the same purposes, the colour from it is more permanent, and in many instances the colour obtained is much more beautiful. The precipitates from a decoction of the wood are more yellow than the Brazil woods, which give the colours dyed by it a certain degree of richness not obtained with the other woods. It is not so easily affected by alkaline substances, and appears to contain more tannin than the Brazil woods. With it

Protosulphate of iron, gives a brownish black precipitate.
Persulphate, a reddish brown.
Protosalts of tin give the solution a very bright carmine red colour, but little precipitate.
Lead salts, a rich orange precipitate after standing some time.
Acetate of copper gives a light reddish brown.
Nitrate of silver, a reddish yellow precipitate.
Perchloride of mercury, light orange by standing.
Alum gives the solution a beautiful red colour.

This wood may also be used for browns and other composition colours where Brazil wood is commonly used ; it is more soluble in water, and has other advantageous properties which bid fair to render it a substitute for many purposes in which the best Brazil woods are now employed.

Barwood must also rank in this series. This is a wood of which no good chemical description has yet appeared. As a dyewood it possesses many peculiar properties, and is also becoming extensively useful in the dyehouse. It contains a very great quantity of colouring matter, but is very slightly soluble in water. This difficulty is overcome by a very ingenious arrangement. The colouring matter, while hot, combines easily with the proto-compounds of tin, forming an insoluble cake of a rich red colour; the goods to be dyed are impregnated with protochloride of tin combined with sumac ; the proper proportion of barwood for the colour wanted is put into a boiler with water and brought to boil ; the goods thus impregnated are put into this boiling water containing the rasped wood, and the small portion of colouring matter dissolved in the water is immediately taken up by the goods. The water thus exhausted dissolves a new portion of colouring matter which is again taken up by the goods, and so on, till the tin upon the cloth has become, if we may so

express it, satisfied—in other words, saturated. A good deal of attention and skill is necessary to know the exact point to take the goods out of the bath, otherwise the dyer may either have the colour poor, or by being in too long, give it a brown colour. It is not therefore every dyer who can dye good barwood red.

The following method, with a little attention, will give the finest shades of red. For every 20 lbs. of goods, whether cloth or yarn, take 4 lbs. of sumac well boiled in a sufficient quantity of water, to allow the goods to steep in it without being hard pressed, the clear decoction of sumac being taken off as soon after being boiled as possible; to this is added two ounces, by measure, of sulphuric acid (vitriol); the goods are allowed to steep in this for ten or twelve hours. If 6 lbs. of sumac be used for the 20 lb. weight of goods, four hours steeping will do. When the goods are taken from the liquor they are wrought through the *spirits*, prepared as formerly directed (Chap. VII., p. 45,) at the density of 3° Twaddell, or 1·015 specific gravity. They are wrought in this till they assume a rich light lemon colour, or say fifteen minutes, then washed in cold water until there is no perceptible taste of acid; after this they are put into a tub of hot water and well rinsed. One pound of barwood is taken for every pound of goods, and put into a boiler sufficiently large to allow the goods sufficient freedom to float through it. The goods prepared as above are put into this boiler about ten minutes previous to boiling; they are wrought in this for about twenty minutes after boiling; the exact time of taking them out of the boiler must be judged according to the shade of colour wanted. With this, as with all other colours, there are considerable differences in their proportions; some prefer weaker decoctions and longer time; others vary the quantity of sumac only; some the strength of spirits and the quantity of barwood; but in all fancy colours, weak solutions and long time very seldom give clear bright colours, the goods appearing as if partially worn. Barwood red is a beautiful, rich colour, and is the most permanent of all the fancy reds.

Barwood cannot be used for any composition colour in the same manner as the other red woods are, probably owing to the little quantity of colouring matter which water dissolves from it.

III. Safflower or Carthamus.—This is an annual plant, cultivated in Spain, Egypt, and the Levant. There are two varieties of it, one having large leaves, and the other smaller ones; the last is the best. It is only the flower of this plant that is used for dyeing. When the flowers are gathered, they are squeezed between two stones to express their juice; they are afterwards washed with spring water; next taken in small quantities, and pressed between the hands and laid out upon mats to dry. These cakes are covered up during the day to prevent the sun from shining upon them—which would not only destroy the colour, but dry the cakes too much, and thereby cause further deterioration. They are kept exposed to the dews of night, and turned over occasionally, till dried to the proper point, when they are packed up for the market. It is in this state they are procured by the dyer.

Safflower contains two colouring substances. The one is a yellow, very soluble in water, and of no use to the dyer. To free the safflower from this yellow colouring substance, is a particular part of the manipulation of this dyestuff. The other colouring substance is red, and is extracted from the vegetable after the yellow substance has been washed away, by means of alkaline carbonates. The substance is used very extensively for dyeing the various shades of pinks, crimsons, roses, &c., upon silk, and also for the same colours upon cotton, with lavender, lilac, pearl. The mode of preparing safflower for the purpose of extracting the red matter from it, was for a long time that recommended by Bertholett, and followed by all other writers upon the subject; namely, putting a quantity into a fine bag, "tramping" it with the feet in water until the yellow colour was dissolved, and washed away; the mass left was then treated with an alkali to extract the red matter. But although this red colouring matter is considered insoluble in water, it will be found that the bag, in which it is tramped, becomes a deep crimson red, which can only be produced by the partial solubility of this red matter. This, however, appears to be promoted by a peculiar influence exerted by the cloth on the matter in contact with it, as we have never been able to discover any real colouring matter in the water which passed through. Whatever be the cause, there is experienced a considerable loss. To avoid this, the safflower is put into a tub without any bag, with as much water as will cause the whole to float freely. A very little tramping will be sufficient to reduce the cakes to a soft flocculent mass, which is the sole use of tramping. We may remark, that if a piece of cloth be put in amongst the safflower while tramping, it becomes red; but if steeped in the water which is expressed from the safflower after being tramped, it does not turn red. The safflower, after being tramped, is removed to a tub or cask, having a false bottom with a plug in it, and covered with fine haircloth. The vessel is filled with clean water, and let out by the plug at bottom; filled again, and so on, until the water passing through it is not coloured yellow. After this it is put into a measured quantity of pure water—about three gallons to the pound of safflower—in which is dissolved a little carbonate of soda, or carbonate of potash, (pearl ash does well,) about an ounce to the pound of safflower. Some kinds require less than others; but care ought to be taken that too much is not used, as it destroys the brightness of the colour. This, being well mixed with the water, is put into the tub containing the safflower; then being well stirred and allowed to stand for about 7 hours, the plug is taken out and the clear liquor drawn into a proper vessel. This liquor contains the red dye which has been extracted by the alkali. The remaining safflower is afterwards washed by pouring upon it a little more water made slightly alkaline; but if fine light colours are to be dyed directly from the solution, this second extract does not so well answer, the shade is not so pure. The liquor extracted in this manner contains both red and yellow colouring matter. For this reason silk goods are not dyed directly by this extract, as the silk takes up a portion of the yellow which renders the colour more of a flesh hue than is due in the rose and pink. To dye silks, any old cotton yarn is dyed first by the safflower extract; the cotton takes up nothing except the red. This cotton is then thoroughly washed in cold water till the water coming from it is perfectly clear; it is then steeped for a little in water made slightly alkaline by carbonate of soda or potash, which extracts the red from the cotton, and forms the dyeing solution for silk. The silk to be dyed pink, generally receives a *bottom* or *ground* by passing it through a weak solution of cudbear or archil, so as to form a flesh white or light lavender—the depth being regulated according to the shade of pink wanted. It is then put through the safflower solution, which must previously be rendered acid by a little *lemon-juice vinegar*, or sulphuric acid. When the safflower liquor is exhausted, the silk is washed in clean cold water, and finished by passing through a little water made acid by lemon juice or tartar; neither vinegar nor sulphuric acid should be used in the finishing process.

To dye cotton pink, the liquor is used as directly extracted from the vegetable; the goods require no previous preparation, except to be well bleached. The quantity of liquor used varies according to the shade required; one pound of safflower to the pound of cotton gives a dark rose; and the other shades in the same proportion.

The goods are first wrought in the alkaline solution for five or six minutes and then taken out, and vitriol added to the solution until it tastes decidedly sour; the goods are again immersed and kept working in this till the solution is perfectly exhausted. Exhaustion is known by the operator holding a little between him and the light; if there is no tinge of red, the solution is spent. The goods are now to be well washed by passing through three or four tubfulls of clean cold water; they are then finished through a little water made so as to taste sour with tartar.

It must be borne in mind that, in dyeing with safflower, the water ought to be pure and always cold; a very little heat destroys the beauty of the colour; they must also be dried cold, and preserved carefully from sunshine. The colours obtained by safflower are the prettiest that can be had upon cotton, but they are amongst the most fugitive.

The most beautiful lilacs, puces, and lavenders, are obtained by safflower and prussian blue; but it is one of the most difficult colours to produce of equal shade. The goods are generally dyed a blue first, by nitrate of iron and prussiate of potash, (see Chap. VII., p. 46,) and then put through the safflower solution previously made acid; but the rapidity with which the cloth takes up the red, renders it almost impossible to get a perfectly even dye. Another method is to dye the cloth in the first instance pink, and then to dye it blue. This method gives a

more equal dye, but the mode is liable to serious objections: the nitrate of iron used has always free acid, which materially destroys the red of the safflower, and even although the nitrate of iron were neutral, this evil is not overcome, and the resulting colour has not the same beauty as that blued first; and besides this, a portion of the safflower is dissolved by the nitrate of iron, thereby creating considerable loss. These difficulties may be almost wholly avoided by using instead of the nitrate the persulphate of iron, which may be thus prepared:—Dissolve some protosulphate of iron (copperas) in water, and bring it to the boiling point; then add nitric acid by degrees, till all effervescence ceases, or no red fumes are given off. By this means the iron is peroxidized. This operation must not be performed in any metallic vessel on account of the property which persalt of iron has of dissolving all metals. To the peroxidized salt-solution, ammonia is added so long as any precipitate falls; this is now well washed with hot water, filling up the vessel, allowing the precipitate to settle, throwing off the clear liquor, filling again with hot water, and so on; three or four times will commonly be sufficient. A little ammonia remaining does no harm. To the precipitate is added a little sulphuric acid, which dissolves the peroxide of iron, and any slight quantity of ammonia which remains; by a little evaporation the whole will crystallize in lavender-coloured crystals. If crystallization be attained, the crystals may be used, dissolved in cold water; if not, a little of the solution may be taken, and the operation of dyeing conducted as with nitrate of iron. A little free acid in this salt does no harm.

IV.—Bark or Quercitron, is the inner bark of a tree (the *Quercus nigra* of botanists) which grows spontaneously in North America. Its dyeing properties were first made known to the public by Dr Bancroft, in 1784. Two years after, he obtained an act of parliament, vesting in him the exclusive use and application of it for a certain term of years.

This dyedrug contains a good deal of tannin, and a yellow colouring matter which has got the name of *Quercitrin*. It is crystalline, and has a pearly lustre. Bark was extensively used in the dyehouse for many years for the purpose of dyeing yellow, and almost completely superseded the use of fustic both from its beauty and also its cheapness; but its use for that purpose has been superseded by the bichromate of potash. Its principal use now in the cotton dyehouse is to form the ground for browns, (as already noticed,) and for dying green upon light muslin cloth. The quantity of tannin combined with it makes it very useful for olives; goods impregnated with iron, and passed through a decoction of bark, take a beautiful olive. The proper mordant for this dye is pyrolignite of alumina. Alum and chloride of tin make also an excellent mordant. In dyeing greens upon cloth, the goods are impregnated with pyrolignite of alumina, and then put through a decoction of the bark: but in dyeing light shades of green, much attention must be paid to the preparation of the decoction. This is made by pouring boiling water upon the bark. If deep dark greens are wanted, this method is best; but if light greens be wanted, the water should not be above 86° or 90° Fah.; at this heat there is only the finest yellow colouring matter dissolved; but by a higher temperature the tan and other matters are dissolved, and the colour obtained becomes more or less brown. This peculiarity, however, makes it better as an ingredient in browns, olives, &c.

The mode of dyeing brown with bark and the use of yellow spirits, as described in a former paper, is not very suitable for cloth. The best mode is the following:—Impregnate the cloth with pyrolignite of alumina, and dye it yellow in the same manner as given for dyeing greens. A bath is then prepared by logwood and Brazil wood, about one part of the former to two of the latter; the goods are then wrought in this mixture for 10 minutes, when a little alum is added, and they are wrought 10 minutes longer; they are then washed from this and dried. If the ingredients be well proportioned, this method gives beautiful shades of brown.

V. Fustic.—This dyestuff has been long known. It is uncertain when it was introduced as a dyedrug, but mention is made of it in a book published in 1692. The botanical name of the tree which produces this drug is *Morus tinctoria;* it contains two colouring matters; the one resinous and not soluble in water; the other very soluble in this menstruum, producing a deep yellow colour, having a light orange cast. This substance was also long used for dyeing yellow; but is not now used for that purpose upon cotton. It is still used extensively, however, for that purpose, when the colour is to be produced upon woollen and silk; and it is the principal ingredient used for dyeing greens upon these substances.

A good deal of cotton is dyed green by fustic, especially yarn. The yarn is first dyed blue by the blue vat, and then passed through a little pyrolignite of alumina; it is next wrought in a hot decoction of fustic, which communicates a beautiful rich shade of green. Fustic is also used along with some kinds of Brazil wood to give a richness to red colours; and also as an ingredient in drabs, fawns, olives, and what is termed iron browns. The method of dyeing dark fawns and browns is this:—The goods are first dyed a good deep orange, by passing them through a solution of annotta, and washed from this; a tub is then prepared with a mixture of sumac, fustic, and a little logwood; the goods are wrought in this for some time; after this, a little copperas is added; the goods are again immersed and wrought for six or seven minutes; they are then washed and put into another tub containing fustic, with a very little logwood and Brazil wood; after working a little this is *raised* with alum, then washed and dried. The relative quantity of the ingredients used must of course be regulated according to the depth and particular hue wanted.

IMPROVEMENTS IN SPINNING ROLLERS.

We have been applied to by various parties connected with the preparation of fibrous materials, for information as to the means of preventing the injurious effects of wrapping or "licking," as it is technically termed, of the cotton, flax, &c., on the rollers. Cotton-spinners in particular are often extremely inconvenienced by this casualty, which has a ruinous effect upon the yarn, both as regards quality and quantity produced. It is generally understood that the chief cause to which the evil is to be attributed, is the dampness or humidity of the atmosphere; the position in which the carding machines of a cotton factory are commonly placed, namely, on the ground-floor of the building, must act very disadvantageously in this respect. A preparation for giving a glossy and elastic surface to the rollers, in order to mitigate this evil, as well as to prevent the grooving action which they undergo, from the friction of the fibres passing in contact with them, has long been a desideratum. A patent has been lately taken out for this purpose, by Messrs. Judson and Banton, of Ashton-under-Line.

The rollers to be used in spinning cotton, silk, silk-waste, and flax, are constructed in the ordinary manner, by covering an iron roller with a layer of woollen cloth, and afterwards with a layer of leather; the patentees then apply one or more coats of the composition, varnish, or japan, employed in manufacturing the varnished or japanned leather, known as enamelled or patent leather, or of the composition, varnish, or japan used by japanners, or any other composition, varnish, or japan which possesses sufficient elasticity. Instead of covering the rollers with plain leather, and afterwards varnishing the same, they may be covered with a layer of enamelled or patent leather, or of leathor which has been coated with an elastic composition, varnish, or japan, and a coat of varnish applied over the seam or joint of the leather, and at the ends of the rollers; or the rollers may be covered with a layer of linen or other fabric, in place of the leather, and have the varnish or japan applied thereto.

In the application of this invention to the wooden rollers used in spinning wool, the patentees coat pieces of leather with the composition, varnish, or japan, and cover the rollers therewith; the seam or joining, and the edges, being afterwards coated with varnish or japan. Unprepared leather may also be used for covering the rollers, and then varnished. Instead of leather, strong cotton or woollen felt may be employed, and coated either before or after its application to the rollers.

Another branch of the same patent also relates to the covering of leather straps or bands used for driving machinery with any of the elastic compositions, varnishes, or japans before mentioned, which will render them impervious to water and more durable; the varnish or japan is applied to one or both sides of the leather, either before or after it is made into straps. It also consists in covering driving-straps or bands, made of woollen or cotton felt, or of linen or cotton tape, with any of the above compositions, varnishes, or japans, and by this means rendering them impervious to oil and water.

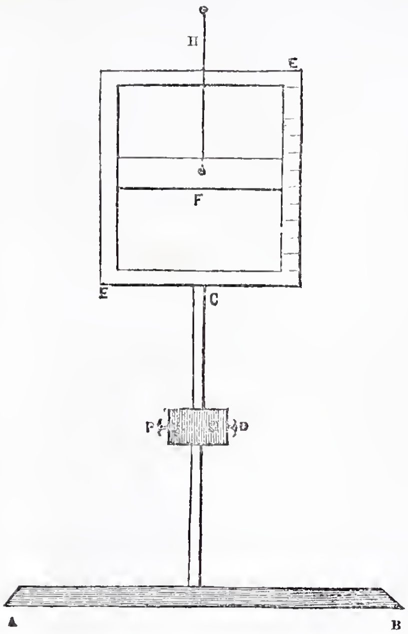
The elasticity of these coverings will, we think, have the effect of preventing the injurious effects of the fluted metal rollers upon the leather, and, being impervious to oil, it will also keep the elasticity of the under-covering of woollen cloth unimpaired, as the oil from the bearings will be unable to penetrate to it.

INSTRUMENT FOR REDUCING THE SCALE OF FIGURES.

The following sketches represent an invention, which, as it has supplied a great want in the case of the writer, may, it is believed, be found similarly useful to others under like circumstances; it is for reducing the scale of figures, such as busts and the like, in order to copy them in ivory, &c.

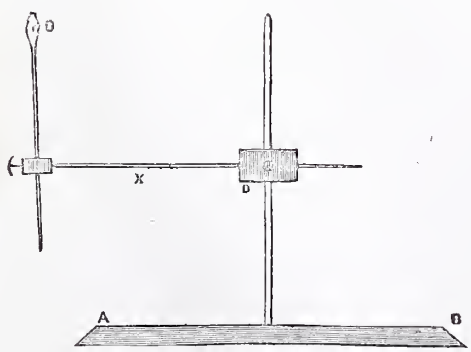
Description.—The instrument may conveniently be made of brass. A B is the stand, made solid and heavy, to give stability

Fig. 1.—A Front View.



to the apparatus; into this is inserted the lower end of the upright, C, which is simply a strong wire, and may be of any convenient length. Upon this upright is carried a sliding socket, which may be fixed at any height desired by the pinching-screw, P. The use of this socket is to regulate the height of the arm, X, which passes through a hole in it, and may be fixed at any point of its length by means of the second pinching-screw, D. On the top of the upright, C, and supported by it, is a frame, E E, of two inches in breadth, composed of brass, and graduated on one side; within this is a sliding-bar, F, which moves parallel to the bottom of the frame; it is moved by the wire-rod, H. In fig. 2 is shown the arm, X, supporting at one

Fig. 2.—An End View.



extremity a rod, O; this rod passes through a socket on the end of the arm, X, and can be fixed at the height desired by means of a little pinching-screw in the socket; the upper end at O is the eye-hole, which can thus be placed at any distance or height in relation to the frame, E E.

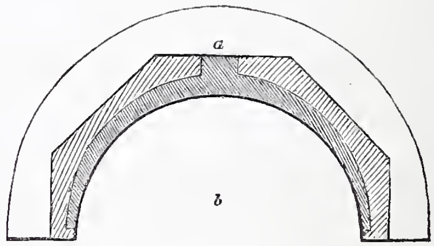
Use.—Having got the widest part of the figure to be copied exactly within the side bars of the frame, E E, by adjusting the distance of the instrument from the figure, and observing through the eye-hole, get the lowest point of the figure on the base line of the frame, and bring down the slider, F, to the highest point; this determines a reduced scale for the figure, which may be applied in the ordinary way.

RABBITT'S ANTI-FRICTION JOURNAL BOXES.

Some years ago, Mr. Isaac Rabbitt of Boston, Massachusetts, obtained an American, and afterwards a British patent, for a mode of lining the brasses of journals with an " anti-attrition metal," for the purpose of reducing friction, and which seems to us to be worthy of notice, on account of its simplicity and reported efficiency.

The metal (which is known in America as Rabbitt's patent metal) is a composition of tin and antimony, the tin greatly predominating. The claims of the patentee do not, however, extend to the metal, but only to the mode of applying it. This consists simply in forming the brasses with ribs or ledges, projecting inwards, to retain the metal in its place when under the pressure of the journal. The ledges determine the size of the journal boxes, and project inwards a fourth of an inch or more, according to the size of the journal. To line the brasses with the soft metal, they are placed separately over a half cylinder of iron, which exactly fills the ledges, and clamped down upon a flat plate; the metal is then poured in through a hole bored in the brass, and speedily sets on the metal core; this being removed, the brass is ready for use, and no polishing is necessary.

The annexed figure shows a cross section of a brass prepared in the way described; *a* is the hole through which the lining metal is poured upon the core, which then fills the semicircular space, *b*. The ledges are equal in depth to the internal lining,



and completely enclose it, both transversely and longitudinally. The brass is thus simply a retaining box or frame for the soft metal lining.

The advantages claimed for this simple contrivance are, that it prevents the heating and consequent cutting and destruction of the bearings, while, at the same time, it admits of a great saving of oil. Mr. Rabbitt has, in fact, simply removed the objection hitherto made to tin bushes—the anti-friction properties of which have long been known—that the metal readily yields under the journal when the pressure is considerable, by which the bearing is destroyed. The ledges (and intermediate ribs, when the bush is very large) prevent this occurring; the soft metal is retained in its place, as it cannot escape by the ends, and the bearing is preserved.

The anti-friction journal boxes are now very extensively used in America; on the Baltimore and Susquehanna Railroad they were introduced a good many years ago, and with good effect. In a letter, by Mr. Howard, the president, to the Honourable R. Williams, secretary to the Committee of Naval Affairs, Senate, United States, it is stated that the Company paid 1000 dollars for the right of using the invention in their locomotives and cars, and would not now relinquish it for a much higher sum, as by its application the machinery is rendered much more durable and effective, and the cost of repairs and the consumption of oil are greatly diminished.

In consequence of this, and other similar recommendations, a formal act of Congress was passed, authorizing the secretary to contract with Mr. Rabbitt for the right to use his anti-friction boxes in the construction of the steam machinery of the navy; they have in consequence been introduced into several vessels, and are stated to be "a truly important and useful improvement."

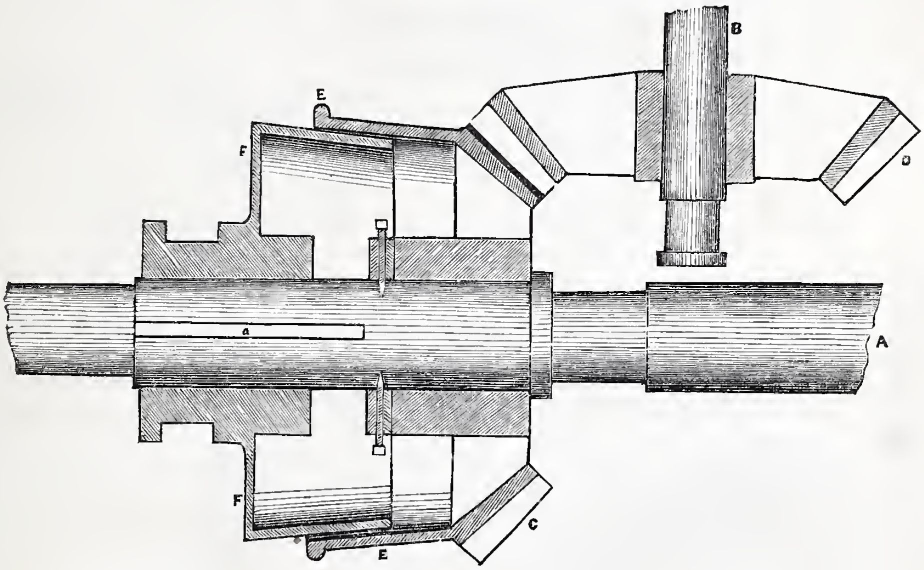
MODES OF TRANSMITTING GRADUALLY THE MOTION OF A PRIME MOVER

TO THE MACHINERY TO BE DRIVEN IN STARTING.

In circumstances where portions of machinery are driven only at intervals, serious inconvenience, and indeed serious mischief, often results from their being suddenly thrown into gear with the driver. This is less felt, and less complained of, when the motion is communicated by belt-connections; these possess a certain degree of elasticity, and allow of a certain amount of *slip*, which beneficially modify the intensity of the first impulse of the driver. But, under circumstances in which the power is transmitted by rigid connection of spur and bevel gear, motion must begin instantaneously—a state of rest must be changed into one of *full* velocity on the instant that the connection is completed. This, it is manifest, when the velocity is considerable, cannot be effected without producing a corresponding degree of *shock* and strain upon the moving parts of the machinery brought into action—for which it is necessary to make proper allowance in point of strength in their first construction, otherwise destruction would speedily ensue. But this additional weight of gearing is itself an inconvenience; and, in order to avoid it, several contrivances have been devised to bring up the speed gradually, with only partial success.

Among the best, and best known of these contrivances, is the cone-movement, frequently applied to dash-wheels, and sometimes to lathes. It is shown in the annexed drawing, in which

Fig. 1.—Section of cone-movement.



A A is the main or driving shaft, and B the shaft through which motion is to be communicated to the machinery to be driven. On the shaft, A A, is a bevel wheel, C, which, gearing into another similar wheel, D, on the shaft, B, transmits the motion. The wheel, C, is cast in a piece with a hollow cone, E E, upon a common boss, which turns loose between two collars on the driving shaft, A A. One of these collars is fitted upon the shaft with screws, as shown in the drawing. A second cone, F F, fitting into the cone, E E, is also placed upon the driving shaft; it is free to move upon the shaft in the direction of its length, but is carried round with it by means of the feather, *a*, which fits into a groove in the boss of the cone.

To put this apparatus into action—that is, supposing the shaft A A is in motion, and that its motion is to be transmitted to B, now at rest, the cone, F F, is pressed forward into the cone, E E, by means of a forked lever, and, coming into contact with its interior circumference, imparts to it *gradually* a motion in common with itself, by means of the friction between the surfaces of contact. The motion is communicated gradually, as the surfaces of the cones at first slide upon each other, the friction being less than the power necessary to start the shaft, B, with its attachments, instantaneously, at the full speed of the driver.

The nicety of adjustment of the form of the driving cones is, perhaps, the chief defect of this contrivance. When the taper is too great, great pressure is necessary to keep the cones in contact; and when too little, they are apt to become locked, and to cut each other. The proper limits are narrow; in practice the taper is found to lie between a $\frac{1}{32}$th and a $\frac{1}{48}$th of the length; that is, between an *eighth* of an inch in four and in six inches. Perhaps a $\frac{1}{40}$th, that is, an eighth of an inch in five inches, may be taken as the safest taper; we have found an eighth in four inches to be too much, and the same upon six inches to be too little. It may, however, be observed, that the taper must, in some degree, depend upon the extent of the surfaces of contact; for if made larger, the risk of locking (which is a consequence of the one surface penetrating the other) is reduced, and consequently, by augmenting the surfaces sufficiently, the minimum of taper may be given with little risk.

The size of the cones, in relation to the power which they are required to transmit, does not appear to be decided upon with any degree of certainty. Perhaps the best working pair which we have seen in action, are 20 inches diameter and 5 inches deep; they are employed to transmit rather more than a horse-power; so that, for high powers, if made in the same proportion, they would be found cumbersome, if not more inconvenient.

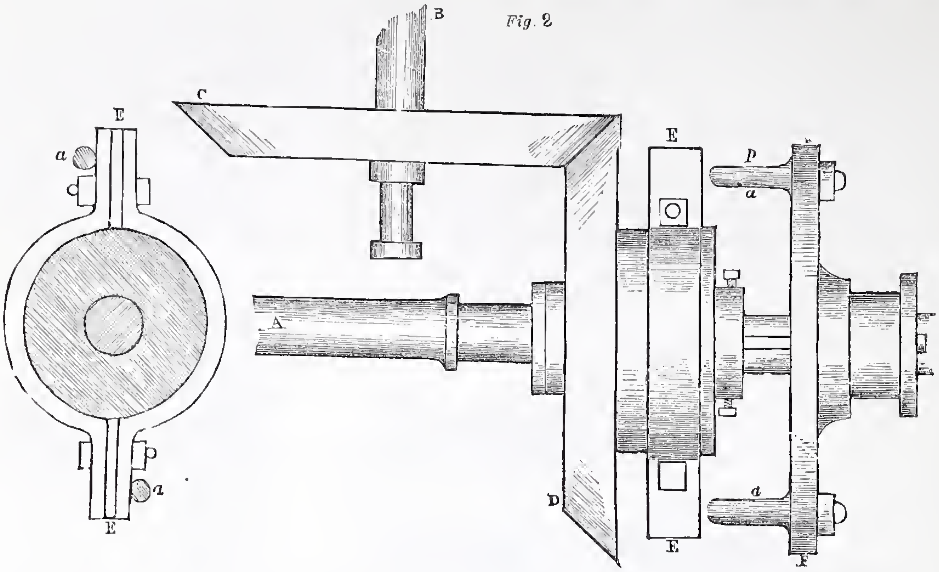
Another mode of accomplishing the object aimed at, is by means of an apparatus, such as that depicted in fig. 2. In this, A A is the driving shaft as before, and B the shaft to be driven; they communicate by the bevel wheels, C and D. The wheel, D, has a large boss cast upon it, and upon this is placed a friction-strap, E E, which is tightened until its friction upon the boss is as great as the greatest power that is to be transmitted. On the driving shaft is also a sliding boss, upon which is a strong disc, F F, with two pins, *a a*, projecting from its face; the boss is prevented from turning upon the shaft by a groove and feather, as in the cone-movement. When motion is to be transmitted to the shaft, B, the boss, with its disc, F F, is pressed forward until the pins, *a a*, take hold of the projecting ears of the friction-strap. On the first impulse, the strap yields upon its bearing, but gradually the friction predominates, and the full motion of the driver is communicated to the shaft, B.

In order to render this contrivance efficient in practice, the bearing surface of the strap ought to be considerably larger than in any example of its application which has fallen under our notice; in fact, to render it thoroughly efficient and durable, it ought to be greater than would, in many cases, be convenient. It must also be observed, that the friction-strap itself must be instantaneously put in motion, and to that extent is the apparatus liable to theoretical objection. The main practical objection, however, consists in the difficulty there is in keeping the strap always at the proper tightness.

A model of another, and in some respects ingenious, mode of

accomplishing the same object, has been submitted to us by an anonymous correspondent. It consists of an application of the friction-strap to a differential movement, in which an internal wheel receives motion from a revolving stud-plate. The arrangement

Fig. 2



is depicted in the annexed sketches, which are made to a scale one-third the size of the model. The crank-handle, H, is to be considered the prime mover as respects the intermediate machinery to which the motion is to be transmitted. In fig. 3, a portion of the cover-plate, P, is removed to show the disposition of the internal parts; and in fig. 4, half the *internal wheel* and revolving *stud wheel* are removed. The central wheel, O, is fast upon the long hollow socket, M, of the cover-plate, P. This plate and socket are cast in one piece, and are loose upon the driving shaft. The opposite cover-plate and socket are also cast in one piece, and run loose on the same shaft; but the flange upon the periphery of this plate is formed into an internal wheel, as shown in fig. 3.

Fig. 3.

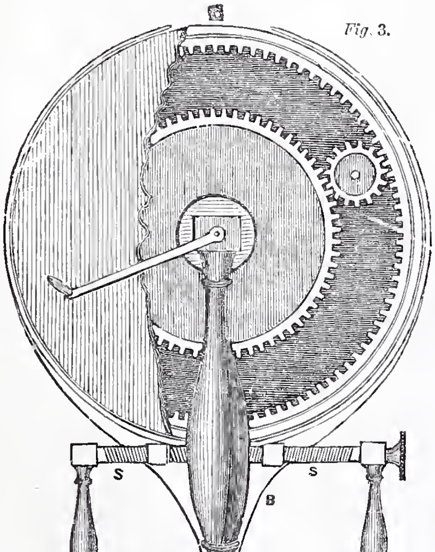
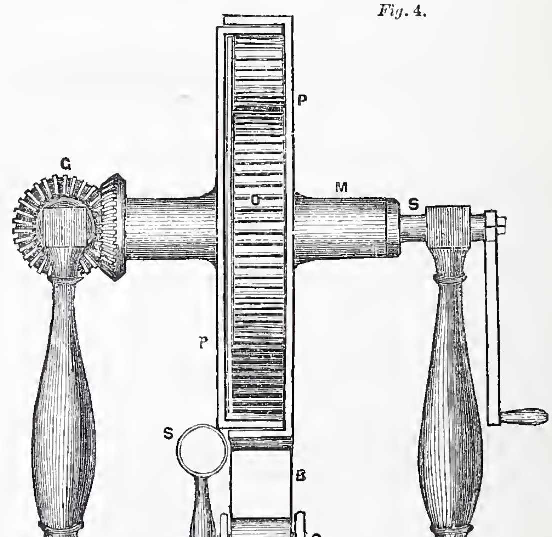


Fig. 4.



This wheel is connected with the central wheel, O, by an intermediate pinion, shown also in fig. 3; this pinion is carried upon a stud in a plate made fast upon the driving shaft, S, within, and parallel with, the planes of the plates, *p* and P. On the socket of the internal wheel, *p*, is a bevel wheel at G, by which the motion is finally transferred from the prime mover to the machinery which is to be driven.

With this arrangement it is clear, that motion being communicated to the driving shaft, S, by the crank-handle, H, the pinion upon the stud of the fixed disc-plate will be carried round between the peripheries of the two wheels into which it gears; but since it gears with both, it must transfer its motion to that which offers least resistance. In the first instance, then, the central wheel, O, and its plate, P, will be made to revolve; but if this be loaded by any means more highly than the internal wheel, *p*, the motion will be transferred to this last, and the other will remain stationary. This is the result contemplated. The power being applied at H, the whole motion is developed in the central wheel, O, and the plate, P, to which it is made fast; but a friction-band is provided to be brought into operation upon the periphery of the plate, P, which for that reason has a deep flange cast upon it, as shown in fig. 4. The friction-band is marked B, in both figures; it is composed of two parts placed upon a common centre, C, fig. 4; and its action is adjusted by a screw, *s s*, cut with a right and left-handed thread, which works in two nuts attached to the respective divisions of the friction-strap. This part of the arrangement is shown in fig 3.

The central wheel being rendered stationary by the action of the friction-band upon the plate, P, the motion of the driving shaft, S, is communicated to the external wheel, by which it is

transferred to the machine to be put in motion, by the bevel-wheels, G; and as the friction apparatus has in it a certain amount of elasticity, and may be brought into operation gradually, all shock on throwing tho machinery into geer with the power may be avoided. It is also obvious that this apparatus may be used as a means of bringing up the speed of the motive power; for the motion finally transmitted will obviously be in proportion to the difference of the diameters of the fast wheel o and the internal wheel *p*.

This application possesses some ingenuity, and in small mechanism would completely answer the purpose intended; but is not at all adapted for strong geering, where such a contrivance is most wanted. To make it applicable to large geering, it would require to be of a size correspondingly large, which would render the differential-box both expensivo and cumbersome; besides, the fact of the travelling pinion working upon a stud, would render the apparatus more subject to wear and derangement than is consistent with the general oharacter of millwork.

From the preceding observations it will appear that a good means of effecting the object is still wanting. The conditions necessary to bo fulfilled are, simplicity of construction, durability, and easy management; and whatever be the nature of the apparatus, it must be such as to occupy little or no space which would not otherwise be occupied by the usual geering.

FRESCO-PAINTING.

THE EXECUTION OF THE PICTURE.

By Charles H. Wilson, Esq., A.R.S.A.

(Report to the Commissioners on the Fine Arts.)

Of the Outline.—The history of this process, as observable in tho works of Italian artists, is of great interest. We find that whilst several mechanical modes of outlining were adopted for fresco, each artist used these means in his own peculiar way, little influenced apparently by any received rule; and as every artist commonly adheres to his own method, the execution of the outline may assist in deciding on the authorship of a work of art.

The practice of indenting the plaster with a point or stylus is very ancient, and we find that the figures painted in Etruscan tombs were thus outlined; that is, the point was used to mark the external outline of the figure only. It was employed by the early masters at the revival of art in Italy precisely in the same way, in outlining their works in distemper on panel; thus Giotto drew, and his followers; and we find the same practice followed in the Sienese school, with a singular exception, which is, that the figure of the Madonna is entirely marked in with the stylus; that is, not merely the external outline, but the outlines of folds in the drapery are drawn in in the same manner; and a notice of this practice, confined to the school of Siena, is useful, as it establishes a clear distinction between the early pictures of that school and those of the contemporary Florentine masters.

At a later period of tempera-painting (referring at present to easel pictures) the point was used in every part of the picture. It then came to be used, when oil was introduced, in the backgrounds only, which proves that the grounds for oil-painting were of the same nature as those previously in use for painting in distemper; that is, of whiting.

It is very remarkable that, whilst the point was used in distemper-pictures on panel, it rarely was in those of the same period on walls. It is never found in mural paintings by Cimabue, Giotto, Orgagna, or Benozzo Gozzoli, but was employed by Fra Beato Angelico in the architectural backgrounds only of the paintings in the Chapel of Nicholas V. in the Vatican. In this case he may have pounced in his outline with a cartoon, and then have ruled in the lines of his architecture; but as these lines are carelessly drawn down through the figures, an objection may be started to this theory, as the pounced outline of the figure would easily show where to stop. In Masaccio's frescos in the Carmine the lines of the architecture are put in with the point, whilst the figures are not. It is very difficult to suppose that after the background was thus outlined the figures were drawn in with the brush only. It is true the head of Masaccio in fresco, which exists among the portraits in the Florence gallery, is merely drawn in with the brush; but this does not prove that the outlines of entire pictures containing many figures were so executed.

If cartoons were used in these earlier times, what could bo the object of the curious practice of outlining in a rough and free manner on the last coat of plaster laid on previous to tho intonaco itself? This is exemplified in all the frescos by Benozzo Gozzoli in the Campo Santo at Pisa: wherever tho intonaco has fallen down, the outline of the composition is seen marked in with red; and in Sta. Croce in Florence, there are examples in which not merely the outline, but also the colours are sketched in.

It has been supposed by some that these outlines were intended as a guide to the plasterer in spreading the intonaco, but in no case do the joinings in the plaster coincide with them. If we suppose that the composition was thus sketched in to enable the artist to judge of the proper proportions and positions of the figures, what then was the use of his cartoon in this respect? It would have been more easy to place it against tho wall, as is now frequently done.

It is not easy to explain some of these facts, nor does the question much affect modern practice; but the subject is not without interest as connected with the early history and practice of art. The solution that the figures were freely and readily drawn in with the brush after the architecture had been drawn in with a ruler and point, it is not easy to accept.

It is very easy to determine by examination whether the point has been used with or without the intervention of a cartoon; in the first case the line is smooth; in the last sharp, and having a ragged edge.

Another mode of outlining; that is, by pouncing, was extensively adopted. This method of course implies the preparation of a large cartoon; and there was still another mode, in which the outline was first pounced, and then, the cartoon being removed, the forms were retraced with the stylus. This is the practice of the modern Italians, and although imposing names may be quoted in support of it, an uncertain and feeble outline is the result, and, besides, in sudden turns it breaks out bits of the plaster, leaving unsightly holes in the picture.

A few instances may now be given of the different modes of marking the outline adopted by different masters. Luca Signorelli carefully marked in every necessary outline. Andrea del Sarto also used the point. Pinturicchio used it in his works at Siena and Spello. Although the absence of the use of this instrument is no proof that mural pictures are not fresco, its use is a certain proof that they must be so, showing that the lime was wet when the outline was put in, as any attempt to draw with a point on dry lime would merely make a series of ruts with broken edges. The fact that Pinturicchio used the stylus at Siena proves beyond a doubt that, however much these pictures may be finished in distemper, they are begun in fresco.

The practice of Luini may be mentioned as showing his facility in fresco-painting. In his faces the features are merely indicated by straight lines. On such careless outlines he painted female heads, the beauty of which never has been excelled.

Razzi, the Sienese, of a still more impatient spirit, dashed in a few lines on the wall indicating the places of his figures rather than outlining them. He trusted to his facility with the brush, and is often very incorrect in his drawing; still the exquisitely beautiful female faces painted by him in S. Domenico, at Siena, are entirely produced by the brush, the outline previously laid in with the point being out of all proportion; thus the point of the nose and mouth of the St Catherine, as outlined, are fully half an inch below the same features as finished in the painting.

The Venetian masters were by no means careful. Titian seems to have taken little pains in preparing the outline in his fresco-pictures, which he seems hardly to have painted *con amore*, although in many respects they bear the impress of his genius. Pordenone used the point, and in some places where he appears to have changed his mind, he has taken the first thing that came to hand to make an outline,—perhaps the end of his mahl-stick, or the point of his dagger, thus breaking out lumps of plaster and producing irregularities in the surface which he never seems to have thought it worth while to have mended again.

Innocenza da Imola offers in his practice a striking contrast to that of the artists mentioned; he puts in every hair and wrinkle with the point, before beginning to paint.

It might be supposed that the spirit of Buonarotti may have shown itself in the vigorous and impatient marking of his out-

line, but such is not the case; he adopted the slower process of pouncing. There are no marks of the stylus in the Last Judgment. The remarkable distemper picture attributed to him, which hangs in the Tribune at Florence, is drawn in with the point; the Fates in the Pitti are not, neither is it seen in any frescos of his which I could closely examine.

Pietro Perugino pounced all his outlines, and so did his great pupil Raphael; but his pupils again followed each his own fancy in this respect. Raphael did not use the point in his fine works in the Farnesina, and the advantage is obvious; those beautiful creations would have been injured by its use; for, whilst its convenience makes it very proper to use it in works removed to a considerable distance from the spectator, it never should be seen in those which are nearer to the eye, especially if the light comes from the side.

In the Loggia, the outlines of the ornaments bounded by straight lines are put in with the point and ruler, without the intervention of a cartoon; all other lines are apparently pounced; but on minute examination I found that they were pricked on the plaster. It is not easy to understand why so tedious a process was adopted.*

The Caracci and their pupils sometimes used the stylus, but in the great majority of the works left by them in all parts of Italy they preferred the spolvero or pouncing bag.

Painting.—In studying the art of fresco-painting, it is necessary to consult the works of the old masters for examples of execution. In everything that is merely mechanical, we may profitably study the proceedings of the modern Germans; every process may be learnt from their practice, without visiting Italy,—the graceful use of the brush excepted. Amongst the works of the present Italian fresco-painters, there is perhaps no example which it would be desirable to follow. The execution of these artists is to the last degree mannered and heavy; and, however satisfactory may have been the progress of the French in other modes of painting, they have entirely failed in the few attempts which they have made in fresco.

Avoiding the errors into which we may conceive that our continental brethren have fallen in the actual painting of their frescos, we must look to the works of the old masters as examples; in these we shall find painting in fresco, in as many styles, and exhibiting as much diversity of touch and handling, as may be observed in the works of the same artists in oil. There is the same liberty of thought in the treatment of both methods, and genius exhibits its powers with as endless a diversity in the one art as in the other.

We find in the frescos of the old masters every quality of execution that has a name in oil-painting, although those qualities are necessarily exemplified in different degrees. We have transparency, opacity, richness; we have thin and thick painting, nay loading, and that to an extent that cannot be contemplated in oil; we have the calm transparent elegant painting of the Florentines and Romans; the rich variety of the Venetians, and there are cases in which the well-nourished brush of Rembrandt seems represented in the works of the fresco-painters of old Italian times.

The distemper paintings of the elder masters have been already alluded to. It was their practice in laying in the preparatory tints in fresco to make some of these totally different from the colour to be used in finishing in distemper; thus, a dark red colour was almost invariably laid in as a preparation for blue, and this practice was generally adhered to with very few exceptions till after the time of Raphael.†

In the works of Giotto, in the Campo Santo, at Pisa, the plaster seems to have been painted black in the first instance. Time did not permit a satisfactory examination of these works: but there is an example of the use of black as a preparation for blue in the Farnesina, where Daniele da Volterra‡ in his frescos on a ceiling in that edifice has first laid in a coat of black in fresco, and then a coat of blue in distemper.

In some pictures, the blue of the skies has either partially changed or entirely faded, whilst that of the draperies is comparatively well preserved. It is thus evident that from motives of economy different blues were used in different portions of pictures. There are many other examples of this in other parts of Italy.

The Cardinal Bonaventura, in the fresco called the Dispute of the Sacrament, by Raphael, is represented in a purplish-black robe which has been painted over red; this is an instance of the adoption of an indirect process with reference to another colour besides blue. It may be observed that the cardinal was a Franciscan, an order which is distinguished by a brown dress; and, as it is not brown in the picture, this may perhaps be an instance of a change of colour. But one object of this mode of painting seems to have been the security of the colours against change, while another may have been the attainment of more harmony in the tone. In the picture just mentioned, Raphael has followed precept in painting the blues in distemper over red, and these have stood perfectly. In the School of Athens, on the contrary, he has painted in the blues in fresco, and they have perished, or nearly so, as they have in most instances in every part of Italy where blue has been thus used; both in pictures of this and of previous times. In the great works which Raphael subsequently painted in the Stanze he returned to the old practice of painting the blues above red, probably dissatisfied with the crudeness which was the result of using them on the wet plaster. The blue that has thus been generally used seems to have been of a vegetable nature, as in many instances it has changed to a brilliant green. It may be urged that the use of ultramarine or cobalt may obviate all necessity for such preparations, and secure the pictures against change; but whilst the former is by far too expensive a colour, the latter is crude and harsh in fresco. It seems to have been the blue which was used by the Caracci, and in their pictures, as in those of Guido, it will be found to be frequently out of harmony with the other colours; either these have in some degree faded, the blue remaining the same, or the blue has increased in intensity. Dominichino used distemper extensively in his works; but in those of Guercino will be found a triumphant solution of the difficulty. His blues are put in in fresco, and yet are in fine harmony with the other tones; they have generally a warm purple hue, and may be either smalt, or cobalt tempered with a red, such as colcothar of vitriol.

It was the practice to retouch when the fresco was dry, more especially in the shadows; but in some cases it is now easy to detect this retouching. It will generally be found to be proportionably somewhat darker than the painting around; and whilst in many frescos a remarkable polish or gloss may be observed even in situations where that effect could not be produced by rubbing, the retouched parts are invariably dim. This is exemplified in the Evangelists by Dominichino in the church of S. Andrea della Valle at Rome. These are historically known to have been retouched; and in viewing them from particular spots, their surfaces are seen to shine as if varnished, whilst some parts, which it may reasonably be inferred are retouches, such as darks under the arms and in the deep folds of the drapery, are quite flat and dim.*

There are portions in Raphael's pictures which present the appearance just described. In the School of Athens there are a few distemper touches, evidently by the master's own hand, which have darkened; for instance, in one head he has had recourse to distemper to represent the external locks of hair. This seems to indicate a difficulty in fresco which at first sight appears formidable. In a picture by Gaudenzio Ferrara, at Milan, a female head with long flowing locks is represented, and the joining is made next the locks, and has a very bad effect. The difficulty is successfully overcome by the German artists without having recourse to distemper, and without placing the

* A drawing to be pounced must be first pricked; the artist having perhaps to use the same outline again, and being in haste to transfer it to the plaster for the first time, may have caused it to be pricked against the wall, thus making his assistant perform two operations at once.

† Several Italian artists mentioned to me their opinion that a coat of *terra vert* was laid in at times as a preparation for blue; and as in many places I saw this green colour, I at first adopted the opinion; but on subsequent observation, I ascertained beyond doubt that the green was in reality a blue which had changed.

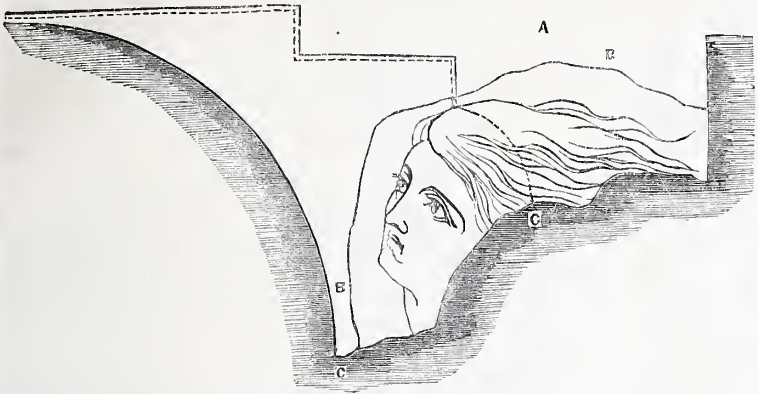
‡ For whom the criticism of Michael Angelo's drawing of a large head, still to be seen on the wall, was much more probably and appropriately intended than for Raphael.

* It also appears, from one instance at least, that a retouch in distemper does not change so much from the action of damp as the fresco itself. The pictures by Professor Schnorr, in the Villa Massimi in Rome, are much injured by the action of damp from the soil, and have become light and cloudy. The retouches (for in these early efforts the Professor did retouch) have all become visible, and appear as dark spots. The vehicle employed, as I learned from the artist himself, was yolk of egg and vinegar.

joining so as to injure the appearance of the picture. This may best be exemplified by a sketch: the flying tresses are painted in on the background on one day, and the head is put in the next day; the joining is indicated by the dotted line in the figure. The foliage of trees is managed in the same way. It would be vain to think of cutting round the outline of foliage; the outer leaves and thin projecting branches are executed on the same day with the background, and the cutting is kept quite within these.

To return to the frescos of Raphael. The Heliodorus, Miracle of Bolsena, Attila, and Deliverance of Peter, seem to be pure frescos, with certain exceptions already alluded to. In the first of these pictures there is a portion which exhibits a remarkable contrast to all the rest. The papal chair-bearers, known to be portraits of the artist's friends, are painted rather in the style of Pordenone than of Raphael; the lights are much loaded, and have apparently been glazed, and, as extensive retouching in distemper has evidently been had recourse to, these retouches have become very dark.

Fig. 1.



A, the entire space above the dotted line is painted in one day, and the flowing hair included; the cut being made at the dotted line, C. The line, B B, represents the joining that less careful artists would have made. C C C, boundary of another day's work.

Fig. 2.

Work (or portions of work) of two days. The dotted line shows the cutting. The drapery under the beard is executed the same day as the head.

The ostentatious freedom with which these figures are painted contrasts disadvantageously with the calm dignified execution of Raphael. With regard to the duration of this part of the picture, as compared with the other portions, apparently in pure fresco, that which is so much retouched has certainly stood as well as the rest, with the exception that parts have become dark.

M. Orsel, a distinguished French artist, who has attentively examined the fresco of the Last Judgment by Michael Angelo, says that it is much retouched in distemper, and without doubt by the great artist's own hand. As this distemper has darkened considerably, the present tone of the picture is accounted for, without having recourse to the supposition that the smoke of candles has been the sole cause. M. Orsel says that the retouching of Michael Angelo's great work is all effected by hatching. This fact necessarily leads us to infer that retouching was carried to a great extent in old frescos; but, as will be shown, hatching is also much practised in the actual process of fresco-painting, and it is consequently difficult to form a very correct judgment, in every case, as to what may or may not be retouching. Many important pictures exhibit much hatching, which is probably retouching.

The story of Franciabigio's wrath at the premature exhibition of his fresco in the court of the SS. Annunziata at Florence, may be instanced as supporting the prevalence of the practice under discussion amongst the old masters. The picture was not finished in the artist's estimation; yet as fresco it would be pronounced to be so; all the intonaco is laid and painted upon, but as he esteemed the work incomplete, it is quite plain that he mean to retouch it in distemper,

From these and other examples we find that although as art advanced, the extensive use of distemper, at first prevalent, was given up, and that pictures were chiefly executed in fresco; still the practice was never entirely abandoned; and till art was revived by the Caracci, it may justly be doubted whether there is one mural picture in existence that is entirely completed in fresco.

Indeed after the adoption of fresco-painting, an apparent love of the older practice induced artists to return to it. Pinturicchio adopted it; his pictures at Siena are unquestionably much painted upon in distemper. Those at Spello seem to be executed much in the same way. The pavement in one of these pictures, for instance, is laid in flat with white, in fresco; when this dried the artist evidently outlined two divisions of the stones over it, and he then laid on in distemper the colours which varied the pavement. In the pictures by the same artist in the church of Ara Cœli in Rome, he has begun the pictures in fresco, and then entirely painted them over in distemper; and in all the works of this artist, foregrounds and foreground plants, landscape back-grounds, and probably the skies, are executed altogether in distemper. There seems to be no reason to doubt the durability of this kind of painting, although other objections may be brought against it; but where egg has been the vehicle used, the colour, if loaded, has a tendency to scale off, while the pictures darken and become inky in tone.

The Genoese also abandoned true fresco-painting, and used distemper to a great extent; so much so, that their works may be considered apart under the head of distemper-painting.

It is evident that the practice of the great masters supports the propriety of a certain amount of retouching, and it may be inferred from their works that no very bad results follow from its adoption within due limits. The Germans, however, maintain an opposite opinion, insisting that it is not allowable and quite unnecessary. If adopted at all, the limits seem marked by the practice of Raphael in his later works; but it may be observed that loose opinions upon this subject might lead to careless practice, and in this view of the case the severe injunctions of the German masters are of value.

Transparency.—This important quality is perfectly attainable in fresco-painting. It is found in the works of the Roman and Florentine masters; amongst the latter, more especially in those of Andrea del Sarto; in those of the Lombards, it is admirably maintained; and its excess is seen in those of the Venetians.

It is not easy to explain how transparency is to be attained in fresco; there is, perhaps, no quality in which our German brethren are more deficient; the brushes which they use are to an English eye small for the work, and the first tint laid on with these presents a streaky appearance, which perhaps could be obviated in some instances by the use of larger brushes, and a different mode of using them. It will be easily understood how this streaky appearance is produced. Having first given one wipe of the brush full of colour, the artist follows it up with another, the colour sinking in instantly, and as he cannot lay the second wipe exactly to the edge of the first, the one overlaps the other in parts, and those parts are consequently twice as dark as the others which have got only one wipe, and so he proceeds laying a tint composed of light and dark streaks, but nevertheless transparent. This quality is lost in uniting the tint; for he continues to go over the surface till he obtains what he seeks, a quiet flat tone, which, however, generally proves a heavy one. Now, in the ancient examples, this union is obtained without sacrificing transparency. In a church near Conegliano there are some curious frescos by a Venetian painter, in which the excess of this quality is exhibited; they do not merit the name of works of art, and are very slightly executed; the colours seem laid in one wash only, the plaster ground shining through; but these bad pictures prove that it is possible to lay in tints in a transparent and yet flat manner.

Titian frequently makes use of the bare intonaco in particular places; thus, in his fresco of The Healing of the Foot of the Boy, in the Capitolo of S. Antonio at Padua, the shadows are laid in with brown in a very transparent manner, and for the half-tint he has left the bare lime. It may be doubted whether this practice is to be recommended; as it is never found in the frescos of the Florentines or the Romans, and that great fresco-painter, Luini, obtains equal lightness and transparency without having recourse to it. Such a practice gives a work a sketchy character which is objectionable, especially in the principal figures.

How the effect of transparency is to be mechanically obtained it remains for the artist to discover by practice.

A Milanese professor says that with a view to transparency it is necessary to lay in the first tints early in the morning, and then to leave the work and not to resume it for two hours. He further says that the lime, if it have any remains of an injurious caustic quality, exhausts its fury, to use his own words, on these first colours, and may be more safely painted on afterwards. It must be confessed that the frescos by Appiani, which he instanced as examples of the practice, are very far from exhibiting the quality of transparency. Other artists, however, hold the same opinion, and it is therefore proper to state it.

*Hatching.**—The prevalence of this practice amongst many of the old masters (for it is evidently not always the result of retouching) seems to prove that they also found a difficulty in getting flat tints. In some of the later masters it is a mere manner, but in earlier and better examples it may have been adopted in the hope of getting a flat tint without destroying transparency. Whatever was the reason, the practice was very general, and it is to be observed that the great masters did not cross in this hatching; the lines lie all in one way, and Signor Colombo of Rome says, that the tempera-hatchings in Michael Angelo's Last Judgment are thus laid on with great evenness and dexterity.

In the works of Raphael, the most perfect of fresco-painters, there is no hatching anywhere, nor is there in those of Correggio. The hatching with which the Cupids of the last named painter in the Convent of S. Paolo, at Parma, are covered and destroyed, is manifestly the work of another hand; the lunettes underneath have fortunately escaped this profanation.

Solid Painting.—This is a quality that is easily attainable. It will be best understood by observing, that whilst the plasterer lays on a preparatory intonaco of lime and sand with the trowel, the artist lays on a finishing one of lime and colour with the brush, and he may employ it as thickly as he pleases. I observed in the works of Pordenone in Sta. Maria in Campagna, at Piacenza, that the lights were laid on with such a body of colour that, before the lime had time to set, the artist's sleeve, or mahl-stick, or something else in his way, has accidentally ploughed through his work, which he has not been able, or has not cared to mend.

Paul Veronese, in his frescos in the Villa Mazer, has charged his lights; and his imitators in their works, both in the above villa and in that of the Obizzi near Padua, have loaded so much that the lights stand up in lumps upon the wall. Such extravagancies, like the washing in of the shadows in the pictures near Conegliano before mentioned, are poor substitutes for a careful imitation of nature.

The lights must of necessity be thicker than the shadows, as there is more lime in the colours of the former than in those of the latter. The great masters laid in their colours without ostentatious handling; their works exhibit no tricks of manipulation; but it is surprising to observe the manner in which some artists seem to have worked their tints. Pordenone has already been alluded to, and Polidoro da Caravaggio produces an effect as if his brush had been full of macguilp, as may be seen in his frescos in Rome.

Glazing.—This process is frequently exemplified in the fresco-works of the old masters. Its most successful application is seen in those of Razzi at Siena, where the celebrated picture called the "Cristo alla Colonna," in the gallery of the Academy, is a particularly interesting example of its legitimate application in fresco; that is, of its use while the plaster is still moist—in this instance parts are made out by means of it, and much lightness and transparency are attained.

Pordenone invented or adopted some process which resembles that common in oil-painting; his works have evidently been glazed after the lime had been allowed to dry—the flesh in all his figures is richly glazed,—the transparent colour filling up the hollows arising from the peculiar loading already described as so remarkably exhibited in his frescos, if they can be called such. Polidoro da Caravaggio seems to have adopted some analogous method, but probably these are the only masters who can be quoted as having adopted a practice so foreign to fresco-painting. Perhaps the artist who painted the papal chair-bearers in the Heliodorus may be added to this brief list. The adoption of such a practice evidently arises from a misapprehension of the legitimate application of fresco-painting. It will be found that the Venetian painters generally had no clear idea of the true mode of employing this art,—even Titian fell into the mistake of trying to produce effects of light and shadow and colours, like those he had been in the habit of producing in his oil-pictures. The light and brilliant colouring of Paul Veronese enabled him to paint with more success in fresco than the generality of his Venetian brethren; but in his works it is evident that this is merely the result of his system, not any attempt at an application of the principles of colour suited to the peculiar art of fresco-painting, which he sometimes practised, and most successfully at the Villa Mazer. Palma Vecchio alone, of the Venetian masters, seems to have truly estimated the powers of fresco. There are two Saints by him in S. Liberale at Castel-franco, which have breadth and dignity.

Razzi has already been alluded to as an artist whose works most prominently exemplify legitimate glazing in fresco; it is not apparent in the works of any other master to the same extent.

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* This term of Art means employing lines in shading somewhat in the manner of engravers, but more freely.

THE SCIENCE OF PHRENOLOGY.

CHAPTER III.

The brain, as we have already proved, is the organ of the mind, not the mind itself. It is admitted there are two classes of phrenologists: the spiritualists, those who believe in divine revelation, and consider the brain as the ORGAN of the mind; and the materialists, those who believe the brain itself to be the mind. These latter have given us a notable specimen of reasoning in the following couplet:—

"Knock out your brains, and you will quickly find,
That, with your brains, you have knocked out your mind."

To which we will only reply, that the eye is the organ on which light falls, and if the above couplet is to be taken as finishing the controversy, we would say—

'Knock out your eyes, and with your precious sight,
You'll quickly find you have knocked out the light."

But light still exists, and the want of the organ is the only preventive of its enjoyment. So, if the brain be knocked out, the mind, not having an organ to operate by, cannot be seen to operate at all in a material world. The brain itself is matter, and is subject to the laws of matter, and, to use a high authority, when the body (and the brain is part of the body) returns to the dust, the spirit returns to God who gave it. We say, then, that the brain is the organ, or the instrument, by which the mind acts. But there appears to be a prior medium between the mind and the brain, and before we consider the brain itself we will notice this medium, which seems to have escaped the observation of phrenologists in general, but which appears to us to be highly deserving the attention of those students who admit the truths of divine revelation, and who (justly, as it appears to us) believe that the truths of science must harmonize with, and never can be in opposition to, the truths of revelation. With Fichte, we say—"To truth I solemnly devote myself. Without respect of party or of reputation, I shall always acknowledge *that* to be truth which I recognize as such, come whence it may; and never acknowledge that which I do not believe. It may be of little importance to the world to receive this assurance, but it is of importance to me to call upon it to bear witness to this my solemn vow." *

The subject, then, which we consider deserving attention, as a prior medium from the mind to the brain itself, is that which was known to the ancient philosophers by the term 'astral-spirit,' and which has recently been treated of in a masterly manner under the term NERVE-SPIRIT, by Mr. Wilkinson, in his splendid work, "The Human Body, and its Connection with Man." According to this theory, the nerve-spirit seems to be an embodiment of the nervous fluid, being that which unites the body with the spirit, and has a kind of plastic force to raise up an aerial form; and, as has been well observed by a talented authoress, "being the highest organic power, it cannot by any other, physical or chemical, be destroyed; and when the body is cast off, it follows the soul, and as, during life, it is the means by which the soul acts upon the body, and is thus enabled to communicate with the external world, so when the spirit is disembodied, it is through this nerve-spirit that it can make itself visible." †

"The existence of an animal spirit has great historical probability attached to it. For the course of knowledge has consisted, not in confirming abstractions, but in merging them in some adequate reality, such as we are now claiming for the life and spirit of the brain. The concrete form of things, or the tracing them home, is the final victory of knowledge touching mere existence. So long as life is an indeterminate phrase, applied without distinction to the whole system, the study of that life has not commenced, for its presence has not been gained; but when its proper currents are found, and the mind traverses them, then the separate knowledge of their properties can begin, but not sooner. And moreover, the triumphs of this age are peculiarly due to the introduction of the mind to the empire of the fluids. The steam-engine, and its nervous spirit, steam; the railway, and its locomotive fluid. the train; the wire, and its electric spirit, show the practical benefits of the subordination of solid to the fluid. And in human progress, it is the fluid and the modifiable that give motion and impulse to the otherwise fixed. What are quickness, conception, and imagination, but the fluids of the mind? Regard them at work, and you can bring them under no other analogy. They stir the old hard world, and permeate all things, and, like nervous fluids, are present in a moment where their mission is, with the power of arranging and quickening virtue that they have received in the fountains of thought. Indeed, I see not that there is any known sphere of things whose analogies do not cry aloud for the existence of a fluid brain, governing the solid, and, like it, organized, though on a more living plan. Thus, until a nerve-spirit be admitted, how can the science of the brain be in fraternity with the other arts and sciences?

"The doctrine of a nervous fluid seems further to arise out of the construction of the system from successive pieces, each higher and broader than that preceding it; for this ladder takes us up to regard the mind itself as supremely nervous. Now, each part has its centre in itself, but also is traversed by the part above it, on its way to the surface, whither all the pieces, the high and the low, arrive alike immediately, or are represented. Thus the mind comes down through everything, and its spirit glitters in the face. And thus all the actions of man—automatic, sensual, and animal—may be shot and pierced from the quiver of life, until they are nothing but rational and spiritual actions. It is to be remarked, however, that the visible solids terminate with the brain. If, then, the mind has fibres representing it in the brain, as the brain has fibres representing it in the spinal cord, the former fibres must lie in the fluids, for the solids belong to the brain itself. Thus, while the brain, or organism, terminates in its own centres, the cortical substances, or supreme solids, the mind enters into these by a series of corresponding fluid organisms, which represent the living or active portion, as the solids represent the recipient or passive. This is but imagination: yet imagination is the youthful eye of science, and provided it owns to its name, it is an innocent as well as a suggestive power. Therefore we proceed to imagine, that the mind broods above the brain, as the conical ether sits above the planetary air; and further, that the mind, or spiritual reservoir, fills all the interstices of the brain, where, however, it is determined by suitable fluid envelopes, which accommodate, temper, and envelope it, until it is brought into ratio with the fixed mechanism of the cerebrum. Hence, its solar vibrations are fixed in the bodily organism, as light is felt on the earth through the splendid shiver of a medium which the air includes between its parts; and hence there are as many kinds of nervous or cerebral spirit as there are nerves and brains, for it is the openness or intervalling of the latter that admits, and gives quality or fibrillation to, the former. The brain, doubtless, is made with an express view to this recipiency—the fluids which, when entered by the soul, become nerve-spirits, are also predetermined; and hence there is the same ratio again between the mind and the nerve-spirit, as there is between the brain and the spinal cord, in that the parts of both are alike, but differing in breadth or degree." ‡

The brain has been very carefully described in Dr. Spurzheim's Anatomy, and we shall now proceed to give a brief description of that work, illustrating our remarks by such engravings as are calculated to convey correct ideas to the reader on its structure, form, and development. The brain is a collective term, which signifies those parts of the nervous system, exclusive of the nerves themselves, which are contained within the cranium: they are, the cerebrum, cerebellum, and medulla oblongata. They are invested and protected by the membranes of the brain, and the whole together constitute the encephalon (ἐν κεφαλῇ, *within the head*). The brain consists of two substances, the one of nervous or medullary fibres, and the other of a pulpy or gelatinous substance, variable in tint, being found occasionally grey, reddish, yellowish, pale, or dark; this substance is denominated cortical or cineritious.

* Fichte: A Biography. Chambers' Papers, vol. ix., p. 16.
† See Crowe's Night Side of Nature, p. 167.
‡ Wilkinson on the Human Body.

Many of the insect tribes are brainless, but they are furnished with ganglia, or small collections of cineritious and medullary matter, which subserve the purpose of mere existence. From the simple ganglion, the next process seems to be the formation of the spinal marrow, or that nervous matter, which may be termed a string of ganglia, included within the spine. The spinal marrow of a calf is quite as large as that of a man; the cerebrum of a calf is not one-third so large as that of a man. From the spinal marrow, all the regular nerves, or nerves of motion, sensation, and those which convey information of muscular condition, take their departure. An injury inflicted on any one part of the medulla spinalis, destroys the power of sensation and motion upon which those nerves are distributed that take their departure from it below the part injured. In worms and caterpillars, nature has gone no further than the bestowal of the power of sensation and motion (from the medulla spinalis), and their manifestations are found in perfect accordance with this endowment.

The next class of creatures is endowed by nature with the cerebellum, and a very limited portion of cerebrum, and consequently a more or less perfect medulla oblongata, which is the upper inlayed portion of the spinal cord.

No sooner does nature advance within the cranium, and commence endowing her product with cerebellum and cerebrum, than mental manifestation becomes accordant with endowment. The catterpillar and the butterfly are one and the same insect, existing under different forms. This is the case, also, with the maggot and the fly. In the one state, these insects are endowed with the medulla spinalis only, together with the nerves attached to it; in the other, the cerebellum, together with a limited portion of cerebrum, is superadded. In the one state, they feed upon the grossest food; in the other, upon the nectar of flowers. In the one state, they are incapable of continuing their race, because destitute of the cerebellum, the agency of which is essentially necessary for that purpose; in the other, they possess the power, because they are then endowed with the cerebellum. In the one state, their movements are of the most simple kind, evincing an almost entire deprivation of motive, and destitution of will, possessing merely the power of prolonging their existence, and of shrinking from impending danger; in the other, their movements are the most complex and varied, clearly manifesting the possession of will; and if possessed of will, they must be possessed of faculties, because the possession of will necessarily supposes a power of choice, which is inconsistent with the mere possession of one faculty, giving birth to only one impulse. In fine, in the one state their existence is merely organic, superadding to it a limited power of performing animal functions; in the other, they appear more the creatures of motive, acting under the impulse of faculties. This exhibition of nature is of the most conclusive character; in it she demonstrates the use and office of the cerebellum, at the same time that she shows us the inevitable consequences resulting from different endowments in the same product.

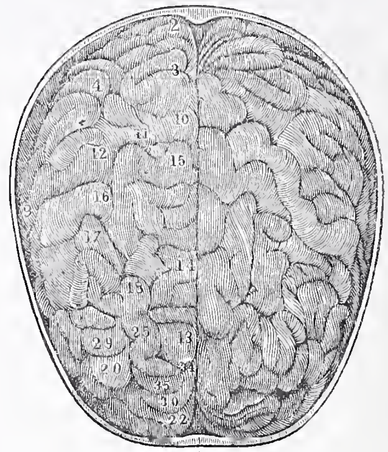
A very considerable portion of cerebrum, together with the entire cerebellum, is allotted to the propensities. This portion occupies the lower basilar part of the brain. It is this, together with a small portion of intellect and feeling, that we perceive developed in many of the reptile tribes, in fishes, birds, and animals. The same kind of development we find coupled with the power of manifesting the same kind of faculty, from man down to the reptile.

In the carnivorous tribes of animals, the propensity to destroy is of all others the strongest. The existence of the organ giving birth to this propensity, is indicated by a width between the ears. The difference, in this respect, between the carnivorous and herbivorous tribes, between the tiger and the sheep, for instance, or between the cat and the hare, is great indeed.

In the animal world, an immense field of observation is presented; the field has not yet been sufficiently well observed with reference to phrenology. Whenever it is, we shall find that the steps of nature can be distinctly traced, from the ganglions to the spinal marrow; and from these to the cerebellum, together with a limited portion of cerebrum, and a more or less perfect medulla oblongata; and from these, advancing onward, by successive layers of cerebral matter, proportioned precisely to the sphere she destines the animal to occupy, until she arrives at man, the *ultimatum* of her labours, the most perfect of her productions, the most extensively endowed with cerebral development. It has been truly said, that, "by taking away, diminishing, or changing proportions, you might form from the human brain that of any other animal; while, on the contrary, there is none from which you could, in like manner, construct the brain of man." *

The engravings which follow are from Dr. Spurzheim's 'Anatomy of the Brain.'

Fig. 1.



A

Fig. 1 represents the upper surface of the brain stripped of the integuments, with the position of the organs, as marked on the authorized bust. The line which divides the brain into two hemispheres is called the falx cerebri. The anterior part is at A. Sir Charles Bell remarks, that "whatever we observe on one side, has a corresponding part on the other, and an exact resemblance and symmetry is preserved in all the lateral divisions of the brain: and so, if we take the proof of anatomy, we must admit, that as the nerves are double, and the organs of sense double, so the brain is double, and every sensation conveyed to the brain is conveyed to the two lateral parts, and the operations performed must be done in both lateral portions at the same moment."—(Anatomy, ii. 381.)

Fig. 2.

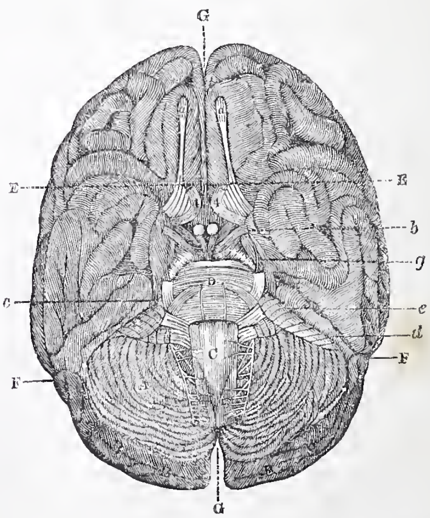


Fig. 2 represents the base of the brain, as it appears when

* See Amos Dean's Lectures on Phrenology. Boston, 1835.

taken out of the skull, the forehead being represented uppermost. The brain is divided by anatomists into three lobes, called anterior, middle, and posterior. The dotted line from E to E is the anterior lobe; those between E E and F F the middle lobe, and those behind F F the posterior lobe. The long flat-looking nerve, *a a*, is the olfactory, or nerve of smell. The round thick nerve, 4, 4, near the roots of the olfactory, is the optic, or nerve of vision, going to the eye. That marked, *b*, is the motor nerve, which supplies the muscle of the eye-ball. A little further back, the fifth pair, *c*, is seen to issue from the arch, D, called the *pons Varolii*, or the bridge of Varolius.* It is a large compound nerve, and divides into three branches,

Fig. 3.

which are ramified on almost all the parts connected with the head and face, and the upper and under jaw. It is a nerve of both sensation and motion, and one branch of it ramified on the tongue is the nerve of taste. Other branches supply and give sensibility to the teeth, glands, and skin. The seventh, or auditory nerve, *e*, is distributed on the internal ear, and serves for hearing. The eighth, or pneumagastric nerve, *d*, sends filaments to the windpipe, lungs, heart, and stomach, and is one of great importance in the production of the voice and respiration; it also influences the action of the heart and the process of digestion.—(See Combe's System, Vol. I. pp. 91, 92. Fourth Edition.)

Fig. 4

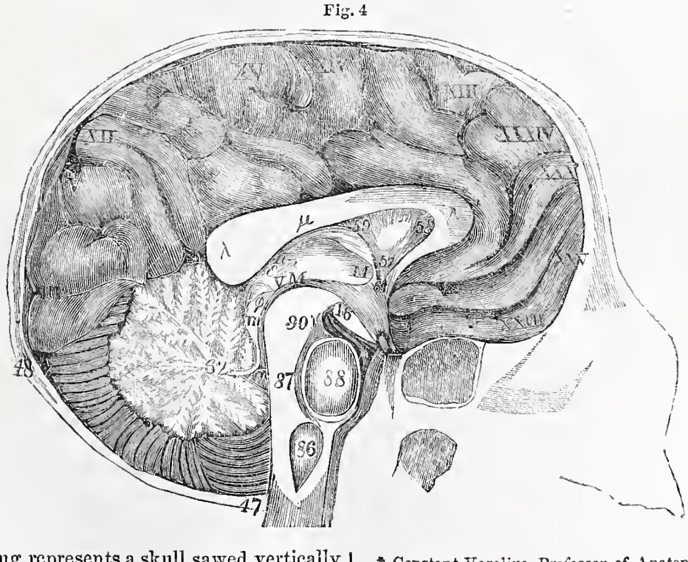


Fig. 3. This engraving represents a skull sawed vertically through the middle of the forehead, the vertex, and the occiput, to expose the exterior and internal surface of the brain, cerebellum, annular protuberance, and medulla oblongata, in their

* Constant Varolius, Professor of Anatomy in Bologna, died in 1578. He dissected the brain in the course of its fibres, beginning from the medulla oblongata, a plan which has since been perfected by Vicussens, and by Gall and Spurzheim. The work containing his mode of dissection, 'De Resolutione Corporis Humani,' was published after his death in 1591.

natural situations. The bone here supports the cerebellum and medulla oblongata. The organs are marked in their respective positions. The figures on the outside of the cranium correspond with the positions of those within. 47 to 48 is the cerebellum, the situation of the organ of Amativeness. From 48 to 49, situation of the organ of Philoprogenitiveness. From 49 to 50, situation of the organ of Inhabitiveness. From 50 to 51, situation of the organ of Self-Esteem. From 51 to 52, situation of the organ of Firmness. From 52 to 53, situation of the organ of Veneration. From 53 to 54, situation of the organ of Benevolence. From 54 to 55, situation of the organ of Comparison. From 55 to 56, situation of the organ of Eventuality. *a*. Olivary bodies. *b*. Annular protuberance. *c*. Entrance of the anterior pyramids under the annular protuberance.

Fig. 4. In this engraving is represented the skull, brain, and cerebellum, cut vertically through the median line, and in their natural situation. The organs nearest the inner table of the skull are marked in numerals.

λ λ. The extremities of the corpus callosum.

μ. The middle part of the corpus callosum.

16. Mammillary body.

57, 58, 59. Septum lucidum.

61. Anterior commissure.

62. Interior of the nervous substance of the cerebellum.

86, 87, 88, 90. Intermediate layers of fibres between the two halves of the cerebral masses.

M. The third ventricle.

m. The fourth ventricle.

Fig. 5.

Fig. 5. This engraving represents a preparation, exhibiting various parts about the base of the brain.

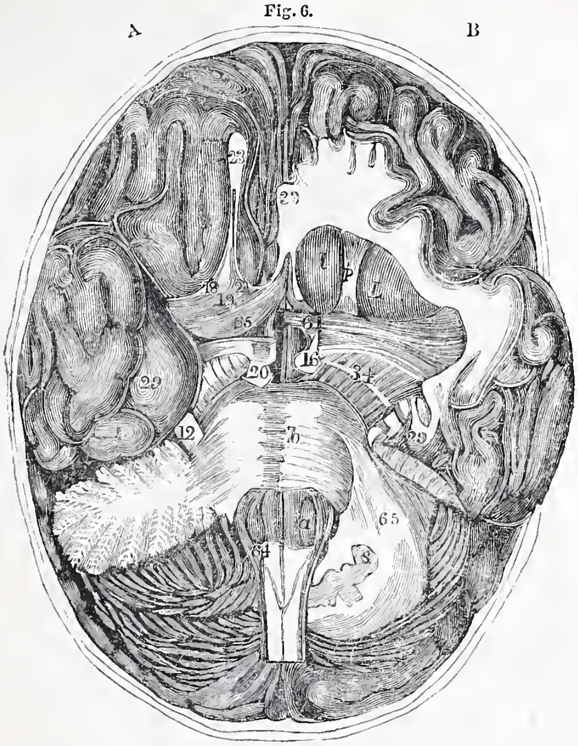
Side B. The hemisphere of the cerebellum entire; its primary bundle is seen to plunge between the facial nerve, 11, and the auditory nerve, 9. The trigeminal nerve, 12, is entirely covered by the transverse fibres of the cerrebellum; the olivary body, *a*, plunges through the transverse fibres of the cerebellum; a portion of the transverse mass is used to exhibit the course of the pyramidal bundle, 1—*c*, which begins to diverge and to be augmented. The optic nerve is in its natural position. On its outer edge the expansion of the nervous bundles, *w w*, in the inferior convolutions of the middle lobe, is seen.

Side A. A vertical section of the cerebellum guided through the entrance of its primary bundle, and the middle of its ganglion, *s*, showing the augmentation of the primary bundle in the ganglion, and the ramifications and subdivisions of the nervous cords. All the transverse fibres of the annular protuberance, which cover the trigeminal nerve and the prolongation of the pyramidal bundle, are cut away. The continuation of the olivary body, *a*, is still covered by the transverse bundles. The optic nerve is raised from the crura, *g*, and cut across at *q*. The pyramidal bundle is thus exposed from the decussation, 1, to the transverse interlacement, beneath the optic nerve. The mass of grey substance, seen on the opposite side, has been scraped off, in order to expose the two cords of the mamillary bodies, 16; the one near the transverse interlacement, 35, the other towards the fornix. The nervous fibres that expand in the convolutions, and contribute to their formation, are cut at *h h*, between 35 and 37, on a level with the anterior commissure, and the middle lobe is removed altogether. The mass of grey substance of the great superior cerebral ganglion (striated body), and a part of the convolutions lying at the bottom of the great fissure, D, between the anterior and middle lobes, are incised in the same direction. The way in which this collection of grey substance is divided by the nervous bundles, P, at its internal, *l*, and its external, L, parts, the mode in which fine filaments traverse the external part of the grey mass, the manner in which the convolutions, 44 to 45, are formed by the posterior cords of the cerebral crura placed before, *q*, and the length and depth of the great ventricle between, the anterior and the middle lobes, are all exposed in this preparation. By the removal of the middle lobe, the side of the great lateral ventricle, N, has become visible. This ventricle is continued backwards, inwards, and forwards, below the crura of the brain, *g*. Only a small portion of the anterior lobe is cut off.

Fig. 6. The great commissure of the cerebellum annular protuberance, *b*, the anterior commissure, and the commissure of the anterior lobe (the anterior fold of the corpus callosum), 39, are here represented.

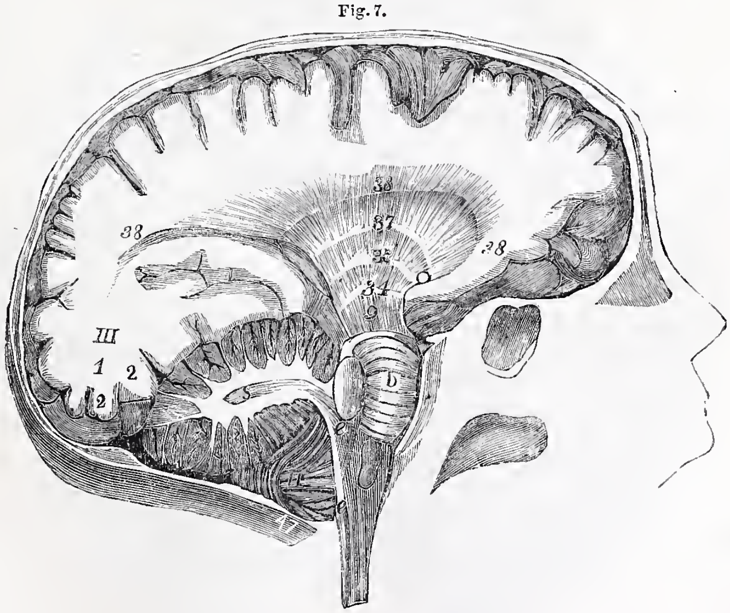
Side A. The anterior edge of the cerebellum is removed by a vertical cut from within, outwards, to expose the conveyance of the uniting fibres towards the median line; the middle and anterior lobes of the brain are entire; the optic nerve is turned

Fig. 6.



back, to exhibit the augmentation it has received from the grey mass situated at its junction; the communication of the white fibres, 63, before the optic nerve, and in front of the anterior commissure, 61, together with the septum lucidum, and the connection of the olfactory nerve with the inferior convolutions of the anterior lobe, are also to be seen.

Fig. 7.



Side B. The lower portion of the cerebellum is removed by a horizontal incision, 65, which passes by the deep channel seen on side A.

Fig. 7. This view of the brain represents the cranium sawed on the right side. The cut passes vertically by the middle of the cerebral and cerebellar hemispheres, and by

the right orbit. The great union of the cerebellum, *b*, is cut transversely behind the exit of the trigeminal nerve, and the external part of the cerebellum is removed. The cerebral parts, which in fig. 5 were situated between the transverse interlacement, 35, and the nervous bundles, P, are taken away, so as to permit a view of the divergence of the fibres in all directions.

By comparing this figure with fig. 5, the different appearance of the same parts, prepared in their situations with the support of the cranium, and deprived of this by being taken out of the skull, will be appreciated.

b. Annular protuberance.
e. Retiform bodies.
1. Decussation of the anterior pyramids.
2. Accessory nerve.
9. Auditory nerve.
34. Transverse band in the midst of the peduncles.
35. Transverse band under the optic nerve.
37. Transverse band of the great superior ganglion.
38. Place where the diverging and uniting fibres decussate.
47. Situation of Amativeness.
III. Situation of Philoprogenitiveness.
S. Ganglion.

Fig. 8. This engraving represents the cranium sawed perpendicularly in the middle line of the head. All the parts which are seen in fig. 4, even to the convolutions indicated by the Roman letters, are here removed by cutting or scraping, in order to show the passage of the pyramidal bodies, 1—*c*, across the annular protuberance, *f*. The augmentation of the diverging bundles in the great inferior ganglion (*optic thalamus*), *p*, and the course of the diverging bundles which issue from them. The course of the bundles which communicate directly with the anterior pyramids, is principally shown in fig. 7, whilst the manner in which the internal and posterior convolutions of the hemispheres are formed by the nervous fibres of the great inferior ganglion of the brain (*thalamus opticus*) is seen in fig. 8.

Fig. 8.

Fig. 9.

A B

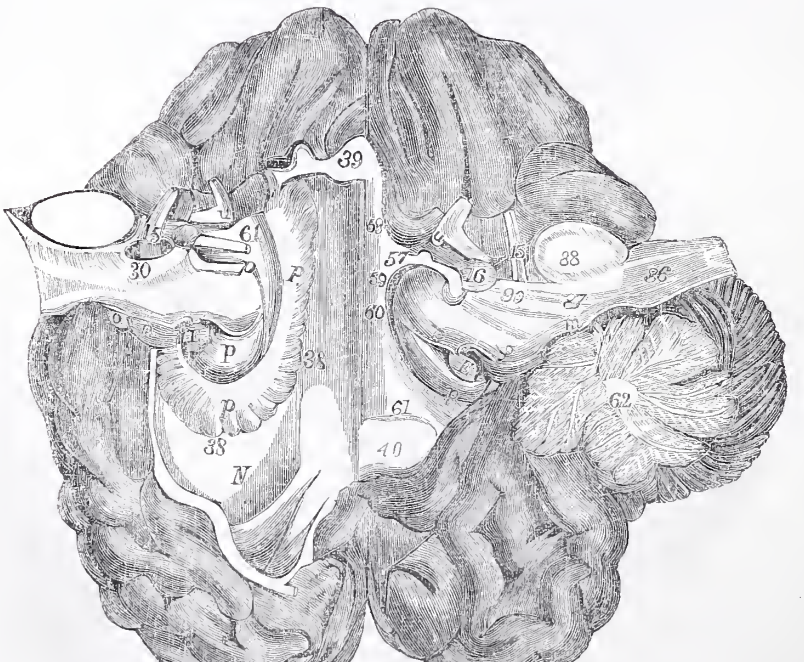


Fig. 9. This engraving represents the brain laid on its superior surface. The side B exhibits the entire nervous mass of the brain and cerebellum, cleft in the median line, from the medulla oblongata to the fornix, and laid on the side. The grey mass behind the junction of the optic nerves, and a small part of the pretended thalami have been scraped away, to expose the

two internal cords of the mammillary bodies, 16, the one running towards the transparent septum, 57, 58, 59, the other plunging into the interior of the great ganglion, *p*, *p*, side A. The medulla oblongata and cerebellum are cut near the annular protuberance. At 30, a part of the median layer is removed to expose the continuation of the oculo-motor nerve into the black substance. The posterior part of the great inferior ganglion, the half of the pineal gland with two cords, and the quadrigeminal bodies, are as on the opposite side, B. The anterior part of the great inferior ganglion is cut on, to show the prolongation of the internal posterior cord of the mammillary bodies, with the transverse interlacement, 36, fig. 5; the septum lucidum, the fornix, the internal portion of grey substance of the corpus striatum, and several internal convolutions of the posterior and middle lobes are removed, to show the great diverging bundles, P, P, and the masses of union known by the name of corpus callosum, in the great cerebral cavities, N, N. The anterior, 39, and the posterior, 40, fold, and the raphé of this mass are preserved. The direction of the converging fibres from behind is forwards and inwards, and from the middle directly inwards. Lastly, the interlacing of the diverging bundles with the fibres of union is presented.

Fig. 10. The brain of a goose laid on its upper surface. Side B. The cerebellum and the hemisphere of the brain entire; the medulla oblongata cleft along the median line, and one of its halves put aside.

41. Upper surface of the primary part of the cerebellum.
42. Inferior surface of the primary part of the cerebellum.
43. Tubercle of the fourth ventricle in fishes.
n. Anterior part of the quadrigeminal bodies.
p. Great inferior ganglion (*thalamus*).
u. Junction of the optic nerves.
45. Cerebral convolutions behind the great fissure.
61. Anterior commissure.
w. Fibres in connection with the external edge of the optic nerve.

Fig. 11. The brain of a goose laid on its superior surface. Side B. The half of the brain and medulla oblongata, as in B, fig. 10; but the inferior and posterior part of the cerebellum

Fig. 10.

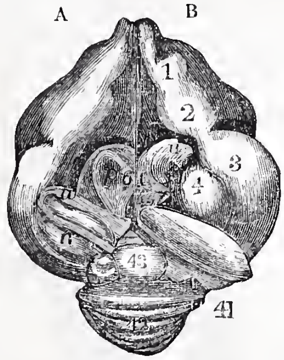
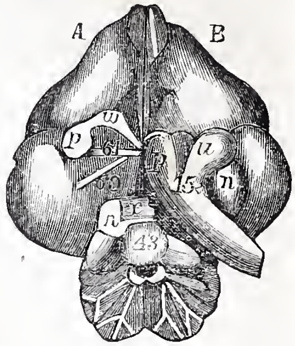


Fig. 11.



is here cleft to exhibit its lamellar structure. The optic ganglion and the optic nerve are taken away to show the continuation of the anterior commissure, 61, and the entries of the crus, *p*, into the hemisphere.

43. Tubercle of the fourth ventricle in fishes.
n. Anterior part of the quadrigeminal bodies.
x. Commissure of the quadrigeminal bodies.
15. Common oculo-motor nerve.
60. Fornix.
p. Great inferior ganglion (*thalamus*).
u. Junction of the optic nerves.
w. Fibres in communication with the external edge of the optic nerve.

Fig. 12.

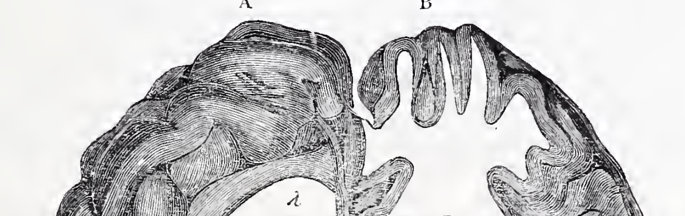


Fig. 12. The human brain laid on its base. The primary part of the cerebellum and the corpus callosum are split along the median line. The posterior surface of the medulla oblongata, the posterior pyramidal bodies, the primary bundles of the cerebellum, and a third portion of the retiform bodies, *e*, *e*, the interior of the fourth ventricle, *m*, the communication of

the cerebellum, *y*, with the quadrigeminal bodies, *n*, *o*, and their union, *x*, the origin of the sympathetic nerve, 13, the pineal gland, E, with its two anterior cords, the posterior commissure, *v*, the soft commissure, 46, and the anterior commissure, 61, cleft. On the side A, only the fornix and the septum lucidum are removed, to expose the striated bodies and thalami lying beneath.

Side B. The primary bundle of the cerebellum, and the parts seen on the surface of the side A, have been removed by a horizontal cut from within outwards, and from before backwards, on a level with the white fibres, situated in the fourth ventricle, *t*. The internal portion of the anterior part of the brain has also been cut away by a vertical incision, in order to expose the division of the striated bodies into two parts, *l*, L, by the passage of the great bundles, P.

Figs. 13 and 14. The brains of geese laid on their inferior surfaces.

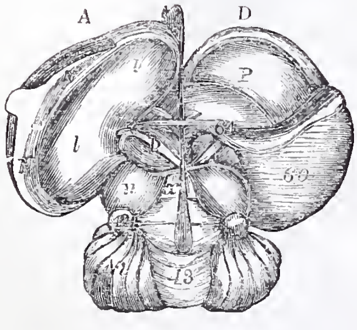
Fig. 14. Side B. The hemisphere of the brain put aside,

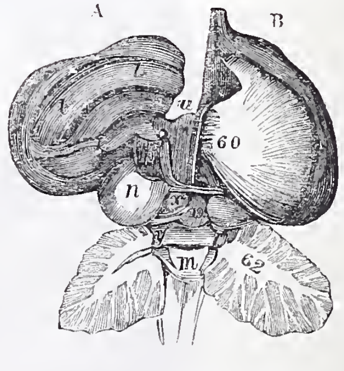
Fig 13. Fig. 14.

and the cerebellum cleft along the median line, to show its lamellar structure and internal cavity, 62. Side A. The optic ganglion, *n*, opened; a part of the crus and interior internal portion of the brain to the junction of the optic nerves removed; part of the crus, and of the striated bodies, seen interiorly remaining.

Fig. 13. The cerebellum cleft along its interior surface, and spread out on each side; the optic thalami on both sides, *n*, and the striated bodies, *l*, *l*, on side A, are in the natural state; whilst on side B, the radiated layer of cerebral substance is visible anteriorly, P. The anterior commissure, 61, is perceived in its full length, the posterior portion of the hemishere, 60, untouched.

By studying attentively these engravings, and comparing the different preparations, the reader will be furnished with as accurate an idea of the brain as is necessary to understand the illustrations to be hereafter introduced. It is not indeed essentially necessary to be acquainted with the anatomy of the brain, but it is most desirable to be so. We shall only add an engraving of the cranium, with a brief description of its bones, and then pass to an illustration of the several organs.





THE CRANIUM.

The cranium is composed of eight separate bones, namely, one occipital, two parietal, one frontal, two temporal, one sphenoid, and one ethmoid. These are seen in the engraving above.

A. The sphenoid bone.
B. The temporal bone.
C. The occipital bone.
D. The parietal bone.
E. The frontal bone.

M, P. The mastoid process of the temporal bone.

m, *a*, *e*. *Meatus auditorius externus;* or, the external opening of the ear.

S, S. Sutures or seams, by which the different bones are united together.

The ethmoid bone is square-shaped, and situated between the two orbits at the root of the nose. It is perforated upon its upper surface by a number of small openings, from which peculiarity it has received its name, ἠθμὸς, (*ethmos*,) a sieve.

GENERAL INDEX

OF THE

ALPHABETIC LETTERS, ROMAN NUMERALS, FIGURES, AND GREEK LETTERS,

USED AS REFERENCES IN THE ENGRAVINGS OF THE BRAIN.

CAPITAL AND ALPHABETIC LETTERS.

A and B.—Sides of preparation.
D.—Convolutions at the bottom of the figure of Sylvius.
E.—Pineal gland.
L.—External portion of the great superior ganglion (striated body).
M.—Third ventricle.
N.—Great lateral ventricles.
P.—The bundles of the striated bodies.
S.—Ganglion of the cerebellum.
a.—Olivary bodies.
b.—Annular protuberance.
c.—Entrance of the anterior pyramids, under the annular protuberance.
d.—Transverse band below the pons Varolii.
e.—Restiform bodies.
f.—Passage of the anterior pyramids, through the annular protuberance.
g.—Peduncles of the brain.
h.—Section of the bundles which go to the middle lobe.
i.—Origin of the trigeminal nerve.
k.—Exit of trigeminal nerve.
l.—Internal part of the great superior ganglion.
m.—Fourth ventricle.
n.—Anterior pair of the quadrigeminal bodies.
o.—Posterior pair of the quadrigeminal bodies.
p.—Great inferior ganglion (*thalamus*).
q.—Corpus geniculatum externum.
r.— " " internum.
s.—Ganglion of the cerebellum.
t.—White fibres in the fourth ventricle.
u.—Junction of the optic nerves.
v.—Posterior commissure.
w.—Fibres in communication with the external edge of the optic nerve.
x.—Commissure of the quadrigeminal bodies.
y.—Valve of Vieussens.

INDEX TO THE ORGANS,

As given by Dr. Spurzheim in his Anatomy of the Brain; marked also in these Engravings.

I.—Organ of Destructiveness.
II.—Amativeness.
III.—Philoprogenitiveness.
IV.—Adhesiveness.
V.—Inhabitiveness.
VI.—Combativeness.
VII.—Secretiveness.
VIII.—Acquisitiveness.
IX.—Constructiveness.
X.—Cautiousness.
XI.—Approbativeness.
XII.—Self-Esteem.
XIII.—Benevolence.
XIV.—Reverence.
XV.—Firmness.
XVI.—Conscientiousness.
XVII.—Hope.
XVIII.—Marvellousness.
XIX.—Organ of Ideality.
XX.—Mirthfulness.
XXI.—Imitation.
XXII.—Individuality.
XXIII.—Configuration.
XXIV.—Size.
XXV.—Weight or Resistance.
XXVI.—Colouring.
XXVII.—Locality.
XXVIII.—Order.
XXIX.—Calculation.
XXX.—Eventuality.
XXXI.—Time.
XXXII.—Tune.
XXXIII.—Language.
XXXIV.—Comparison.
XXXV.—Causality.

NOTE.—There is a slight difference in the numbering in this index and that of the authorized bust; but the situation on the head is, of course, precisely the same. Some of the nerves in the previous index are not exhibited in the engravings we have copied; but the reader will find it advantageous to consult 'Spurzheim's Anatomy of the Brain,' for further information. The work is in most Medical Libraries, as well as in those of Mechanics' Institutions.

INDEX TO THE GREEK LETTER REFERENCES.

α (alpha).—Lateral fissure of the spinal cord.
β (beta).—Mesial edge of the spinal cord.
γ (gamma).—Anterior pillar of the fornix.
δ (delta).—Abdominal root of the spinal nerves.
η (eta).—Dorsal root of the spinal nerves.
ϑ (theta).—Commissure of the spinal cord.
λ (lambda).—Extremity of the corpus calossum.
μ (mu).—Middle part of the corpus calossum.
φ (phi).—Aqueduct of Sylvius.

INDEX OF FIGURES.

1. Decussation of the anterior pyramids.
2—3. Accessory nerve.
4. Hyperglossal nerve.
5. Mesial fissure of spinal cord.
6. Pneumogastric nerve.
7. Glossopharyngeal nerve.
8. Ganglion of the auditory nerve.
9. Auditory nerve.
10. Abductor nerve.
11. Facial nerve.
12. Trigeminal nerve.
13. Superior oblique nerve.
14. Section of the annular protuberance.
15. Common oculo-motor nerve.
16. Mammillary body.
17. Cineritious tubercle.
18. External root of the olfactory nerve.
19. Middle root of ditto.
20. Optic nerve.
21. Internal root of the olfactory nerve.
22. Infundibulum.
23. Bulb or ganglion of the olfactory nerve.
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35. Transverse band under the optic nerve.
36. Transverse band of the bundles which go to the middle lobe.
37. Transverse band of the great superior ganglion.

INDEX TO FIGURES—CONTINUED.

38. Place where the diverging and uniting fibres decussate.
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40. Posterior fold of the corpus callosum.
41. Upper surface of the primary part of the cerebellum.
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43. Tubercle of the fourth ventricle in fishes.
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47—48. Situation of Amativeness.
48—49. " Philoprogenitiveness.
49—50. " Inhabitiveness.
50—51. " Self-Esteem.
51—52. Situation of Firmness.
52—53. " Veneration.
53—54. " Benevolence.
54—55. " Comparison.
55—56. " Eventuality.
57, 58, 59. Septum lucidum.
60. Fornix.
61. Annular commissure.
62. Interior of the nervous substance of the cerebellum.
63. White fibres which unite with the septum lucidum.
65. Horizontal section of the cerebellum.
70. Nervous bundles of the organs of the affective faculties.
86, 87, 88, 90. Intermediate layers of fibres between the two halves of the cerebral masses.

Our limits will not allow us to investigate the configuration of the different races of man, but we may state their number to be eleven, distinguished by four colours, as follows:—

I. WHITE.—1. ARABIAN: the nose prominent, the lips thin, the beard abundant, and the hair straight or flowing. 2. ABYSSINIAN: the complexion hardly becoming florid, the nose prominent, and the hair crisped.

II. BROWN.—3. MONGOLIAN: beardless, with the hair perfectly straight and very long. 4. HOTTENTOT: Negro features and close woolly hair, and the stature diminutive. 5. MALAY: features not prominent in the profile, the complexion darker than in the preceding races, and the hair straight or flowing.

III. BLACKISH-BROWN.—6. PAPUAN: features not prominent in the profile, the beard abundant, the skin harsh to the touch, and the hair crisped or frizzled. 7. NEGRILLO: Apparently beardless, the stature diminutive, the features approaching those of the Negro, and the hair woolly. 8. INDIAN OR TELINGAN: the features approaching those of the Arabian, and the hair, in like manner, straight or flowing. 9. ETHIOPIAN: the complexion and features intermediate between those of the Telingan and Negro, and the hair crisped.

IV. BLACK.—10. AUSTRALIAN: Negro features, but combined with straight or flowing hair. 11. NEGRO: Close woolly hair, the nose flattened, and the lips very thick.*

Phrenologists have generally described the peculiarities of organization under the *Ethiopian* or *African* race, the *Mongolian* or *Asiatic*, and the *Caucasian* or *European*.

In the Ethiopian variety, the forehead is narrow and depressed; the entire cranium, anteriorly, is contracted, while the back part of the head is large. In this variety the propensities are strong, and the intellect defectively developed.

The Mongolians are an advance on the Ethiopian variety; the forehead is, however, low and slanting, the head has a square form, and the intellect and sentiments are better developed than in the preceding, and the propensities, also, appear stronger.

The Caucasian, including the inhabitants of Europe (except the Northern parts), of Western Asia, and Northern Africa, presents a brain of the finest intellectual organization. The upper and frontal parts of the skull are more developed than in any other variety; the proportions here indicate a vast preponderance over the instruments of sense, and of the common animal wants. Wherever we turn, we may observe the inferior races retiring before the Caucasian. On the colossal continents of America, one tribe follows another to absolute extinction. The same is the case with the Malay tribes of Australia. The death of the last of the aborigines of Van Diemen's Land is already recorded. In Africa, the Arab race, a branch of the same stock, has possessed itself of the whole territory north of the Atlas chain, and in its turn is being expelled by a more energetic and civilized branch of the same great race. In America, Africa, China, and Australia, England has sown the seed of mighty empires. In fine, all that can be regarded as good and great, has mainly sprung from the Caucasian race.†

* Pickering's Races of Man.
† See an able article on Ethnology, in the Intellectual Repository for October, 1852.

CHEMISTRY OF ORGANIC NATURE.

CHAPTER II.

THE ANIMAL KINGDOM.

DISTINCTION BETWEEN PLANTS AND ANIMALS.

THE science of chemistry is usually divided into two branches —inorganic and organic chemistry; the former including the consideration of matter which has never been endowed with the vital principle or life, and the latter embracing all the varieties of form in which living nature is familiar to the eye. We say that the dust we tread on, and the stones which constitute the pavement, are forms of inorganic matter, because they have never been possessed of organs capable of reproducing themselves, or even of adding to their bulk. It has been supposed that there is something more mysterious in the growth of a plant from its seed, than in the production of the crystal of a salt from a saline solution; and that, in consequence, the study of the chemistry of plants and animals is fraught with greater difficulty than that of stones and metallic compounds. The simple contrast of two examples, from each of the divisions of chemistry, will enable a judgment to be formed of the alleged greater mystery in the growth of plants. If we take a hard bean and place it in a glass of water—having previously weighed it—and allow it to soak for some days, we shall find, that on again placing it in the balance, it has gained a considerable addition to its weight; and upon more carefully scrutinizing it, we can also discern the evidence of its incipient germination—in other words, that it has begun to grow. In this instance, the seed has increased in weight simply by the agency of water, and it has begun to expand into a plant by the same influence. Here we have the plain facts. The difficulty lies in explaining *how* the water has made the plant grow larger. To contrast it with a fact from inorganic chemistry, let us recall to mind the production of alum, so important among the manufactures. *Alum slate*, as occurring at Hurlet and Campsie, near Glasgow, contains a quantity of the earth alumina, and through the slate is interspersed a compound of iron and sulphur, (iron pyrites.) By burning the slate in contact with the oxygen of the air, the sulphur is converted into sulphuric acid, a portion of which remains attached to the iron, forming copperas, and the remainder is set free. The latter acts upon the alumina of the slate, and forms a soluble sulphate of alumina, which is dissolved by washing with water. To the liquor a salt of potash is added, and the solution is evaporated. In the course of some time, when the liquor has become sufficiently concentrated, splendid crystals, consisting of eight-sided figures—exactly represented by placing two pyramids base to base—make their appearance. Now these crystals of alum never existed before, so far as we know, any more than those portions of the seeds which have been produced by the action of the water, in the previous instance cited. They have, as it were, grown under our eyes. In both of the examples which we have considered, one set of forms of matter has assumed another shape; but the nature of the exact manner in which this change is produced, is equally mysterious in both cases. The difficulty lies in defining *how* the alteration is effected. Bearing this in mind, we are enabled to penetrate in some degree the mysterious veil which appears to envelope the growth of organic substances. For we then know that plants and salts are equally formed by matter which has previously existed in another shape. It is necessary to divest organic chemistry of the apparent difficulties which beset it at the threshold, in order that it may be more carefully studied than hitherto in this country. A knowledge of inorganic chemistry is a necessary introduction to that of organic chemistry, just as a child must crawl before it walks, the study of organic bodies being based upon that of dead matter; for, when we think of the processes of bleaching, dyeing, calico-printing, brewing, distilling, bread-making, digestion, &c., and of the sciences of agriculture and medicine—all departments of organic chemistry—we cannot fail to acknowledge that inorganic chemistry is but the prelude to all important applications.

The products, then, of the animal and vegetable worlds, constitute the subject of organic chemistry. There has been much difficulty in defining vegetables and animals—the former being confined to one spot, and the latter being moveable beings. Some have considered that animals were distinctly locomotive; but it so happens, that many of the lesser tribes of animals are incapable of locomotion, and hence this definition is untenable. Others observing that plants are destitute of sensation, have proposed to ascribe this attribute alone to animals, and define them as nervous beings. But in opposition to this view, we find many inferior animals apparently destitute of sensation, and only supplied with a degree of irritability even inferior to that of the sensitive plant, cultivated so frequently in our botanic gardens; and hence this definition also fails us. We believe that the true distinction between plants and animals will be detected more readily by discovering the nature of the matter by means of which they increase in bulk; or, in other words, by the nature of their food—the term food being a word applied to express the matter which enables plants and young animals to increase in size, and full-grown animals to preserve their forms unimpaired. It is to chemistry then we are to look for an answer to the questions, What is an animal? What is a vegetable? To one accustomed to view only the larger kinds of animated beings, it might seem an easy task to give a reply to these questions. But when we know that nature is simple in her works—that in her glorious field we find no sudden leaps from great to small—that the whole animated world consists of a chain formed of a series of beings, passing down in regular gradation from the most perfect to the most imperfect state,—the lowest plant being closely allied to the lowest form of animal,—it will at once be obvious that to say where plants begin and animals end cannot be a problem of easy solution. To apply, however, the test which we have suggested, let us begin with plants. We find a plant cultivated among the Chinese, and introduced among ourselves, termed the *air plant*, which, by being merely suspended in the air, increases in bulk and weight without even the application of water. This is one of the most simple forms of vegetable life, as the plant has nothing to feed on save the air, which, however, contains all the elements necessary for its growth—oxygen, vapour of water, carbonic acid, and nitrogen. But all these are gaseous bodies or vapours,—while the air-plant is a solid; we thence infer that this plant is capable of reducing gases to the solid state, and of thereby increasing in bulk and weight. According to the present views of persons best qualified to judge, it appears that all plants are endowed with similar properties, and that they mainly subsist by feeding on the gases which surround them, by converting these gases, by means of the organs with which they are endowed, into the solid forms of the vegetable kingdom, —so endless in figure, but yet so lovely, that the greatest familiarity renders them only objects of superior admiration. When we turn to the animal world, we find that the individuals of which it consists are incapable of condensing gases; in fact, the least educated person knows, that animals cannot exist upon air; but that they require to imbibe solid matter similar to that of which they consist. Man lives upon animal food, and those kinds of grain which contain matter nearly allied to it. The question, why has grass—perhaps the most abundant vegetable in nature—never constituted a portion of human food, may not strike one as being in its answer fraught with important information; and yet the only reason which can be given for the fact, that it has never been an article of human food, except perhaps, among the lowest portions of the human family, is, because it contains such a small portion of matter similar in its nature to the constituents of man's frame, that the quantity required would be too

voluminous for the digestive capacity of the stomach and other organs. An animal may therefore be defined, to be a being which subsists by appropriating to itself food, similar to that of which its own body is composed. Hence we see the necessity for its locomotion; while a plant, finding its nourishment in the constituents of the air which surrounds it, has its food brought to it by the usual laws of nature. We believe, then, that such will be found the only legitimate mode of separating animals from plants. It is possible that among the inferior tribes of animals, where an approximation is made to the vegetable kingdom, there may be individuals partaking of a semi-vegetable and animal nature,—partly living on air, and partly on solids; although it does not follow that such an occurrence is necessary, yet, from the simplicity and gradation which we find subsisting throughout nature, we might expect to discover some such union of the two kingdoms, or some equally simple transition from one set of beings to the other.

Plants, then, it ought to be considered, are supplied with a more complicated apparatus than animals. For they are capable of generating solids from gases,—or producing from those elements compound bodies which never existed before, —while animals merely take from plants solid food ready prepared for them, and add it without any change to their own substance. Animals, then, it would appear, are made up of plants; whence we infer, that plants must have existed before animals. So strikingly is it the fact, that animals are derived from plants, that it is usual to judge of the fertility of a pasture field by the quantity and richness of the milk (the essence as it were) supplied by the cattle which feed upon it.

Plants, however, are scarcely susceptible of remaining so long without food as animals. Deprive a plant of moisture and air, and it speedily withers and decays. Man is enabled, perhaps, to endure hunger for a longer period than any other class of animals.

Mr. Catlin, while once lecturing on the North American Indians, stated, that when he visited the Mandans, on the Missouri River, some years ago, he found their numbers amounting to 2000; but soon after he left them, the small-pox, introduced by the North-west Fur Company, and the assaults of their enemies, contributed to effect the total annihilation of the tribe. One of the chiefs, described by Mr C. as a man of noble spirit, when he found his friends and relatives dying around him, and that single-handed he could no longer defend himself from the enemies of his tribe, resolved upon terminating his existence by starving himself to death; and although strongly urged by the fur traders to desist from his intention, he, in the most determined manner, adhered to his purpose, and died on the ninth day.

Since plants, then, are less capable of subsisting without food than animals, it would appear that the food of plants is less permanent in its effects than that of animals. But animals have the power of laying up a kind of food, which renders them capable of subsisting for much longer periods than that mentioned, without the use of aliment. An instance, which occurred to the writer, strikingly illustrated this fact:—A poor idiot, who had been bedrid for years, had received a sudden fright by a peal of thunder, which caused him to refuse all sustenance; and so far did he carry his prejudice, that he would allow no water to cross his lips which was not clear and crystal from the spring. In this condition he remained for seventy-four days, when tired nature at last yielded and gave up the struggle. The explanation was simple, but it was as beautiful as it was simple. The poor creature, by want of exercise, and by previously possessing a strong appetite, had become enormously fat. This deposit acted as so much fuel, and enabled respiration to proceed as usual; but as his frame was acquiring no addition, and every part of it was dwindling away, or, more properly, burning away, as soon as the fat was removed the individual became thin and exhausted, and death inevitably closed the scene. The power of the human body, displayed in this fact, we believe to be peculiar, and not to be shared by the vegetable kingdom.

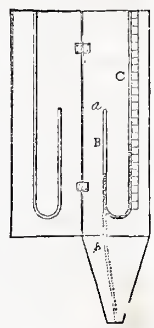
These remarks are intended to delineate the characteristic features of the two living kingdoms of nature, and to show that there is a point at which vegetable unites with animal chemistry, inasmuch as plants supply food for animals. Hence the consideration of the materials of which animals are composed naturally includes the study of the plants, or, at least, of those parts of vegetables upon which they principally subsist. The chemistry of animal substances may therefore be legitimately viewed as including the nature of the substances derived from animals, and of the food from which they are primarily obtained.

MECHANICAL PROPERTIES OF AIR.

EXPERIMENTAL DATA AND PRACTICAL DEDUCTIONS FROM THE SAME—RELATIONS OF PRESSURE, HEAT, AND DENSITY—PASSAGE OF AIR THROUGH ORIFICES.

One of the best ascertained properties of aëriform fluids is their remarkable elasticity. It is in consequence of this elasticity that all fluids of a gaseous nature tend continually to expand and occupy more space; and, if confined exercise, by virtue of that tendency, a certain pressure, depending on their density and temperature, upon the sides of the containing vessel. As in the case of water and other liquids, if allowance be made for the weight of the fluid, the internal pressure is equal upon every point of the vessel; and may be measured by a mercurial gage made to communicate with the interior of the vessel in which the fluid is contained.

A very convenient form of gage for experiments of this kind, is represented by the annexed figure.



It consists of a glass tube doubly bent, and opening through the lower end of the wooden case in which it is fixed. The lower of the three branches, A, shown in dotted outline, passes behind the second branch, B: it is empty, while the other two branches B and C contain in their lower half, a quantity of liquid, usually mercury, but for small pressures and low temperatures, coloured-water is preferable; the specific gravity of water being to mercury as 1 to 13·568, the ranges of variation are consequently in the inverse order of these numbers; that is, 1 inch of variation in the mercurial gage is equivalent to 13½ inches of variation in the water-gage. In the normal condition of the gage, the liquid will stand at the same height in both branches, B and C; but if the conical end of the instrument be inserted into a corresponding hole, in the top of the air-vessel, the air will communicate through the lower branch A upon the liquid in the branch B, which will accordingly be forced to ascend in the branch C, until its pressure becomes equal to the elastic force of the included air or other aëriform fluid contained in the vessel.

By this and similar means it has been ascertained that the elastic force of aëriform fluids, of which atmospheric air may be taken as the type, varies in the same proportion as its density, the temperature being constant. This well-known law, first announced by Boyle, and subsequently established by Mariotte, and hence called Mariotte's law, was recently proved to be true for pressures amounting to twenty-seven times the mean pressure of the atmosphere, by a committee of the French Institute, consisting of MM. Dulong and Arago, appointed to ascertain the elastic force of steam, in some preliminary experiments for executing the objects of the commission. The simple atmospheric pressure is indicated by the height of the barometer at the level of the sea, and is taken generally at 30 inches of mercury—which is slightly greater than the true mean height, as will immediately appear.

The dilatation of air by heat is a property which it possesses in common with all other known forms of matter. The

modification which Mariotte's law receives from the effects of a change of temperature was first stated by Dalton as a result of experiment and confirmed very shortly after by the experiments of Gay-Lussac. It was ascertained by the independent labours of these two eminent investigators, that air, and other aëriform fluids, submitted to the same constant pressure, receive equal increments of volume for equal increments of temperature, provided the pressure to which both are submitted be the same and constant. It was further found by Gay-Lussac, that from the temperature of melting ice (32° Fah.) to that of boiling water (212° Fah.) a mass of air, the volume of which at the former temperature is expressed by 1, expands to a size expressed by 1·375. If the augmentation 0·375 be divided into 180 equal parts, and each of these parts be assumed to measure the effect of a degree of temperature, it will follow from the theory enunciated, that every gas dilates by the fractional part 0·00208 of its volume, taken at the temperature of melting ice, for each degree of Fahrenheit's thermometer. Consequently, the volume of a mass of air being taken as 1, at 32° Fah., its volume at $t°$ Fah. above 32° will be expressed by $1 + 0{\cdot}00208t$; and if v' be the volume when the temperature is $t°$ above 32°, and v the volume when the temperature under the same pressure is at 32°, the relation between the volume and temperature is conveniently expressed algebraically by the equation

$$v' = v\,(1 + 0{\cdot}00208\,t).$$

And since the quantity of matter remains constant, if D' and D be the densities corresponding to v' and v, we have

$$D' \times v' = D \times v;\ \text{that is } v' : v :: D : D'.$$

For it is clear that since the densities of bodies vary inversely as their volume, the densities of the same mass of air at 32°, and at $32° + t°$ must be to each other as $1 + 0{\cdot}00208\,t$ to 1. The weight also for the same volume must obviously be proportional to the density: from this is determined the *specific gravities* of bodies, that is, their weights as referred to a known unit of volume.

The specific gravity of an aëriform fluid is, then, a function of the force by which it is compressed and of its temperature: it is augmented by compression and diminished by heat in the manner indicated. If the pressure on a unit of surface be changed without any alteration of temperature, from the constant value which we have hitherto supposed it to have, and which we may denote by s, to the value s', the density at the same time changing from D' to D'', the law of Mariotte gives the analogy

$$s' : s :: D'' : D' \text{ or } \frac{s'}{s} = \frac{D''}{D'}$$

These equations easily conduct to the following relation between s', D'' and $t°$;

$$s' = \frac{s \times D''}{D} \times (1 + 0{\cdot}00208)$$

This formula is considered to apply to gases, to vapours, and to compounds of both, and either. The co-efficient 0·00208 is the same for all, but $\frac{s}{D}$ differs for different aëriform fluids. Now if the unit of density for atmospheric air at 32° Fah. be ascertained at a particular place on the earth's surface, $\frac{s}{D}$ will manifestly be the pressure there at that temperature. But from the experiments of MM. Biot and Arago, it appears that the specific gravity of mercury to that of air at the temperature of melting ice, under a barometrical pressure of 29·922 inches, is 10462; consequently, if g be the measure of gravity at the place where these experiments were made (observatory of Paris), the value of

$$\frac{s}{D} \text{ is } \frac{29{\cdot}922 \times 10462\,g}{12} = 26086{\cdot}997\,g.$$

For any other place, this quantity must be multiplied by the ratio of the force of gravity at that place, to the force represented by g. The numerical value of g, taken in motion at the observatory of Paris, is 32·1824 feet; but the co-efficient of g is here obtained on the assumption that the air is perfectly void of moisture, and consequently requires correction. It has been ascertained by a process to which we shall subsequently refer, that the ratio of the density of air completely saturated with vapour to air perfectly dry, is the fraction $\frac{10000}{99749}$. We must therefore multiply our co-efficient 26086·997, by that quantity; the result is 26152·64, which applies to air containing its maximum quantity of humidity; and the mean of the two values, 26119·819, may be assumed to apply to the usual state of the atmosphere. It thus then appears, that 26119·819 feet is the height of the atmosphere on the supposition that the density throughout is constant; and that at the earth's surface, reduced to the level of the sea, the barometrical pressure, taken at the temperature of melting ice, is 29·922 inches. To find its pressure under the same conditions, it is only necessary to multiply the height by the measure of gravity on the given base: the result is the pressure. Thus the weight of a cubic foot of air is ·081121 lbs., or 1·297936 oz. avoirdupois, and the height of a homogeneous atmosphere being 26119·819 feet, the weight of a column of one square foot of base is 2118·854 lbs.; consequently the pressure upon a square inch is 14·711 lbs. This pressure measured by water, gives a height of 33·8315 feet, the weight of a cubic foot of water being taken at 62·5 lbs. avoirdupois; and in like manner the altitude of a column of any other fluid of uniform density sustained by the air's pressure, is to the altitude of the mercury in the barometer, as the specific gravity of mercury is to that of the other fluid.

The weight of a cubic foot of air, at the temperature and under the barometrical pressure indicated, being known, and also the amount of expansion for equal increments of temperature, we readily find the following expression for the weight of an equal volume of (dry atmospheric) air under any other barometrical pressure B, and at any other temperature t, above 32°; namely,

$$w' = \frac{w}{1 + 0{\cdot}00208\,t} = \frac{0{\cdot}081121\,\frac{B}{29{\cdot}922}}{1 + 0{\cdot}00208\,t} = \frac{0{\cdot}0027111\,B}{1 + 0{\cdot}00208}$$

Where w is the weight at 32° under a barometrical pressure of 29·922 inches, and w' the weight at any other temperature and under any other pressure.

In calculations requiring a great degree of accuracy, a correction should be given to the factor 0·00208, on account of the effect of vapour; for when the temperature increases, the quantity of vapour in the atmosphere augments at the same time, and as the density of vapour under the same pressure is greater than that of air, a given quantity of humid air will dilate more than an equal quantity of dry air. This correction will be effected very nearly by changing the factor into 0·002, for the mean hygrometrical condition of the atmosphere; so that our expression for the specific weight of a cubic foot of atmospheric air may be reduced without appreciable error to

$$w' = \frac{0{\cdot}0027111\,B}{1 + 0{\cdot}002\,t}\text{ lb., or } \frac{0{\cdot}0433776\,B}{1 + 0{\cdot}002\,t}\text{ oz.}$$

And for other aëriform fluids: if R be the ratio of the density of any gas to that of air, or the specific gravity of the gas, the weight of a cubic foot of it will be

$$\left(\frac{0{\cdot}00271\,B}{1 + 0{\cdot}002\,t} \times R\right)\text{ lb.}$$

From these considerations it appears, that the relation between the pressure, density, and temperature of an aeriform fluid, depends upon experiment; but it may be remarked, that the constants upon which the value of the equations expressive of this relation depend, have been determined with great exactness, and may be employed as the basis of calculation with much confidence. We have, however, re-

garded the air hitherto in a state of rest; let us now consider the condition of motion.

In the first place, let us suppose that there is a hollow cylinder, with a stop-cock fitted into one of its end covers, and that these are otherwise made perfectly air-tight. If the stop-cock be open, the atmospheric pressure on the exterior and interior surfaces will be equal; and therefore, the elastic force of the air within the cylinder being equal to the elastic force of that without, and which we designate by B, there will be no ingress or egress of air through the stop-cock. But if the air in the cylinder be compressed; if for example, the cover of the upper end of the cylinder, which we may suppose to have become moveable as a piston, be weighted, the air under it will be more compressed than that without, and its particles, yielding to the excess of presssure, will escape by the stop-cock. The force by which they escape may also be known, for supposing that, under the circumstances named, a gage such as that already described be fitted to the cylinder, and that the mercury rises in it to a height H: this height measures the pressure resulting from the weight on the piston: the particles opposite the passage of escape provided by the stop-cock will be impelled outwards by the force $B + H$; they will be pressed inwards by the force B; these forces acting in exactly opposite directions, their resultant will be equal to their difference, and that difference is H. The flow of escape will therefore take place as if this force only acted upon the air in the cylinder, and that it escaped into a vacuum.

To determine this velocity, we have in the first place to consider that, the elastic force being equal to the force of compression, the air so compressed must move with a velocity proportional to the force H, by which it is impelled, and which is manifestly equivalent, on the principle explained, to the pressure of a column of air of the height 10462 H, where 10462 expresses the ratio of the specific gravity of mercury to that of air at 32°, that is $\frac{\text{sp. gr. M.}}{\text{sp. gr. A.}} = 10462$, and H is the height of the mercurial column expressed in feet. The air under this force will move with a velocity equal to that acquired by falling down $10462 \times H$ feet; that is, to a uniform velocity $= \sqrt{2g \times 10462 \times H}$ feet in one second of time, the temperature being 32°, and the barometrical pressure 2·4935 feet of mercury. For any other temperature and pressure, and also under a mean state of the atmosphere as respects humidity, we have

$$\frac{\text{Sp. gr. M.}}{\text{Sp. gr. A.}} = 26120 \times \frac{1 + 0\cdot002\,t}{B}$$

where B is to be taken in feet; and, therefore, calling V the velocity of escape, in the case proposed, we obtain by subtraction and reduction

$$V = \sqrt{\left(64\cdot4 \times 26120\,H\,\frac{1 + \cdot002\,t}{B + H}\right)} = 1298\sqrt{H\,\frac{1 \quad \cdot002\,t}{B + H}}$$

where B, the weight of the barometrical column, and H that of the gage column, may be units of any denomination; that is, both feet or both inches; the value of V is feet per second. The co-efficient 1298 is the velocity with which air under atmospheric pressure flows into a vacuum. If, therefore, v be that velocity, P the atmospheric pressure, and p the additional force by which the confined air is compressed by artificial means, then will

$$V = v\sqrt{\frac{p}{P + p}} = v\sqrt{\frac{s' - s}{s}}$$ approximately if the factor t in $1 + 0\cdot002\,t$ be very small.

In this last expression, s is the density of the external air, and s' that of the air in the cylinder. v may be taken, for facility of calculation, $= 1300$.

If a (foot) represent the area of the orifice, the volume of air which will flow through in a second of time is expressed theoretically in cubic feet by

$$1298a\sqrt{H\,\frac{1 + \cdot002\,t}{B + H}} \text{ and approximately } 1300a\sqrt{\frac{p}{P + p}}$$

These expressions give the theoretical issue; but the contraction of the jet or vein of air, in its passage through the orifice, reduces the amount of this issue. Let m be the co-efficient of reduction, and Q the real quantity in a second, then

$$Q = 1298\,a\,m\sqrt{H\,\frac{1 + \cdot002\,t}{B + H}}$$

It now remains to determine the value of m for different forms of orifice. In this we must appeal to experiment; and fortunately the subject has been ably investigated by M. D'Aubuisson* who found that

$m = 0\cdot65$ for orifices in thin plates (tin-plate) varying from $\frac{2}{5}$ to $1\frac{1}{5}$ inch diameter.

$m = 0\cdot93$ for cylindrical adjutages varying from an inch and a half to three inches in length. Diameters as before.

$m = 0\cdot94$ for adjutages slightly conical—taper from 8° to 12°. When the taper is increased, the value of m is diminished, and approaches the limit $m = 0\cdot65$.

But in practice, orifices of escape may in general be considered as belonging to the two last classes: we have rarely a case of the first kind in which the air issues through an orifice of the thinness of tin-plate. We may therefore with safety take $m = 0\cdot93$ as, in practice, even the thickness of the metal approaches to the length of the adjutages employed in the experiments. We may also observe that $a = 0\cdot785\,d^2$, where a is the area of the orifice of escape, and d its diameter. By reduction therefore our expression for the quantity of air which actually flows through an orifice under a given pressure becomes

$$Q = 948\,d^2\sqrt{H\,\frac{1 + \cdot002\,t}{B + H}} \text{ cubic feet.}$$

But in the volume given by this expression, the air is conceived to be of the same density as in the interior of the reservoir, and consequently to be under the pressure $B + H$. To transform this volume into that which it would occupy under any given pressure b, we must multiply our expression by the ratio $\frac{B + H}{b}$ of the two pressures: if b be the simple atmospheric pressure, $= 29\cdot9$ inches of mercury, we have, putting T for $1 + 9\;002\,t$, the following expression,

$$Q = \frac{948\,d^2}{b}\sqrt{H\,(B + H)\,T} = 31\cdot7\,d^2\sqrt{H\,(B + H)\,T}$$

In these last, H and B must be taken in inches of mercury. If we wish to ascertain the weight of the volume of air which passes through an orifice in the unit of time (one second), it is only necessary to multiply the first of our two values of Q by $0\cdot002711\,\frac{B + H}{1 + 0\cdot00\,t}$ lb. the weight of a cubic foot of air under the pressure of $B + H$, and at the temperature $32° + t°$; consequently, if W represent the weight sought in lbs. avoirdupois, we have

$$W = 2\cdot57d^2\sqrt{H\,\frac{B + H}{T}}, \text{ and } \cdot01784\,d^2\sqrt{H\,\frac{B + H}{T}} \text{ if the}$$

diameter d be taken in inches.

In the practical applications of these expressions, we usually, for the sake of facility of calculation, take B and t at mean values; for London $B = 29\cdot89$ inches, and $32° + t = 50°$;

* A detailed account of M. D'Aubuisson's experiments was published in 1826, in the *Annales des Mines*, tome xiii. The tabular results are also printed in his *Traité d'Hydraulique a l'usage des Ingénieurs*, Paris, 1840.

therefore $t^\circ = 18^\circ$, and $T = 1{\cdot}036$. In ordinary calculations, therefore, these numbers may be substituted in the formulæ.

These principles and the practical rules which we have deduced from them in respect to the velocity of escape of atmospheric air under pressure, apply to all aëriform fluids, with a particular modification for each, dependent upon the density. If for example, a gas have a density D, expressed in respect to that of the liquid of the gage, and that it flows through an orifice in the gas-holder under the gage pressure H, the velocity of issue will be that due to the height H augmented in the ratio of the mercury to that of the gas, so that if Q be the quantity of this last which issues in a second of time, we have

$Q = a\,m\sqrt{2\,g\,\frac{H}{D}}$. For any other gas, let D' be the density and Q' the quantity which issues in the unit of time; all other conditions being equal, we have $Q' = a\,m\sqrt{2\,g\,\frac{H}{D'}}$,

$$\text{Also } Q : Q' : : \sqrt{\frac{1}{D}} : \sqrt{\frac{1}{D'}} : : \sqrt{D'} : \sqrt{D}$$

that is, the volumes of two gases which issue by equal orifices and under equal pressures are inversely as the square roots of their densities; consequently, if one of the two gases be atmospheric air, and if G be the specific gravity of the other, the ratio of their densities being that of 1 to G, the quantity of this last which will issue through an orifice in the unit of time under the pressure H will be

$$Q = \frac{31{\cdot}7\,d}{\sqrt{G}}\sqrt{H\,(B + H)\,T}$$

The following cases will illustrate the application of these rules in practice.

1. Let it be required to find the quantity of air reduced to a barometrical pressure of 30 inches, blown into a furnace through a pipe of 2 inch $= \frac{1}{6}$ foot diameter, the mercurial gage standing at a height of 5 inches, the barometer being 29·5, and the temperature being 62°, that is 32° + 30°? Here

$$Q = \frac{948\,d^2}{b}\sqrt{H\,(B + H)\,T} = \frac{948 \times (^1)^2}{30}\sqrt{5\,(29{\cdot}5 + 5)1{\cdot}06}$$

$$= \frac{948}{1080}\sqrt{182\,85} = 11\,85 \text{ cubic feet per second.}$$

2. A gasometer is required to supply 10 cubic feet of coal gas per second, under a pressure of a column of water equal to $1\frac{1}{8}$ inch: let it be required to determine the size of the orifice of escape, for a mean barometrical pressure of 29·9 inches of mercury and mean temperature of 50°.

Here $B = 29{\cdot}9$ and $T = 1{\cdot}036$; the gage column of water is $1\frac{1}{8}$ inch $= 1{\cdot}125$ inch, which is equivalent to a column of mercury of $\frac{1125}{13568} = 0{\cdot}083$ in. $= H$. The sp. gr. of coal gas may be taken at $\cdot559 = G$; and finally $Q = 10$. Hence our last formula by substitution is reduced to

$$10 = \frac{31{\cdot}7\,d^2}{\sqrt{\cdot559}}\sqrt{0{\cdot}083\,(29{\cdot}9 + 0\,083) \times 1{\cdot}036}$$

and by reduction we readily obtain

$$d^2 = \frac{100}{665{\cdot}7}\text{; hence } d = \cdot388 \text{ foot} = 4{\cdot}656 \text{ inches.}$$

Any other questions of a similar nature may be solved in the same manner. It must not, however, be supposed that the rules apply to the motion of air in pipes of any considerable length.

GEOLOGY.

CHAPTER XVIII.

CRETACEOUS OR CHALK SYSTEM.

THE cretaceous, or chalk formation, constitutes the newest depositions of rock termed secondary by geologists. They are intermediate between the oolitic or wealden deposits, and those of eocene beds of tertiary formation, and are thus classed by Mr. Lyell:—

1. The Maestricht beds.
2. The upper chalk with flints.
3. The lower chalk without flints.
4. The upper greensand.
5. The Gault.
6. The lower greensand.

"The newest of these deposits," says Mr Lyell, "is well seen at St Peter's Mount, Maestricht, and at Ciply near Mons, reposing on the upper flinty chalk of England and France. It is a soft yellowish stone, not very unlike chalk, and includes siliceous masses which are much more rare than those of the chalk, of greater bulk, and not composed of block flint, but chert and chalcedony. It is characterized by a peculiar assemblage of organic remains, perfectly distinct from those of the tertiary period. M. Deshayes, after a careful comparison, and making drawings of more than 200 species of Maestricht shells, has been unable to identify any one of them with the numerous tertiary shells in his collection." Mr Lyell then mentions that twelve of the species are found in the white chalk, and five species are common to the upper greensand of France. He also mentions that Count Munster has discovered no less than forty species of microscopic shells belonging to the Cephalopods. These, and the occurrence of Ammonites, Baculites, Hemites, and Belemnites, none of which have ever been discovered in tertiary formations, show that the Maestricht beds should be classed as the newest member of the chalk formation.

The upper chalk usually consists of beds of white soft chalk containing layers of flint or chert nodules, at tolerably regular vertical distances. The lower chalk is generally less white, and is more indurated than the upper; it is frequently interspersed with green grains, and contains comparatively few flints.

"In England, the range of the chalk is one of the most conspicuous features of the eastern and southern counties, in which it forms a noble chain of hills, still partially left (as perhaps they all should have been) open for sheep pasture. These 'wolds,' or downs, are covered with a short sweet herbage, generally bare, and singularly dry even in the valleys, which, for miles, wind and receive complicated branches, all descending in a regular slope, yet are frequently entirely dry, and, what is most singular, contain no channel, and but little other circumstantial proof of the action of water, by which they were excavated. Both the dry valleys and the bare hills have characteristically smooth and flowing outlines very different from the tabular hills of oolite, and the rugged chains of older rocks. The same characters accompany the chalk in France. The greensand ranges are less characteristic, though in Leith Hill and Hazlemere they rise to nearly a thousand feet in height, and thus rival the chalk which generally swells to eight hundred feet; but nowhere, except at Inkpen Beacon, equals a thousand feet. Copious springs flow from the chalk over the subjacent gault, or issue on the dip side at low levels. Wells sunk in the chalk to some hundreds of feet, yield water at different levels according to the impediments in the subterranean currents. Where tertiary clays cover the chalk, as in the basin of London, the boring rod no sooner pierces them, than strong streams arise with a temperature much superior to that of the surface, over which they sometimes flow in a constant stream."—*Philips.*

The chalk hills of England are bounded by a line which stretches from south-west to north-east, and they form three principal mountain ranges. The first, leaving Berkshire, runs north through Bucks, Bedfordshire, and Hertfordshire, to Gogmagog hills, near Cambridge; the second, passing through Berkshire eastward, stretches through Surrey, where it forms the Hag's Back, a beautiful ridge, extending from Farnham to Guildford, and then appears at Boxhill. This branch forms the hilly country and the downs north of Ryegate, Bletchingly, and Godstone. It enters Kent to the north of Westerham, and extends from Folkstone to Dover. One division of this ridge is continued to the north coast of

Kent, and terminates at the North Foreland. The third range, leaving Wilts and Berks, enters Hants, and to the south passes round Petersfield; then, stretching to the east, forms a barrier against the sea along the coast from Chichester, constituting the south downs ranging from Maple-Durham to Beachhead. There is a large detached crust of chalk, in the north of Ireland, overlying the greensand, and overlaid with the basalt of Antrim The superposition of the basalt is well observed at Belfast, Larne, Glenarm Bay, and in the neighbourhood of Ballycastle. There is no vestige of chalk in Scotland or in Wales.

It is extensively developed on the Continent, but nowhere so prominently as in the basin of Paris, where it underlies, as in that of London, tertiary rocks of the Eocene period, and presents the features common to it in England. Detached portions of it occur about Hanover and Brunswick, and other places in Germany. It is also found in Denmark, and the south of Sweden, and in Poland, and part of Russia. Mr Lyell mentions that he had seen it, retaining nearly all the same characters as in England, between Bourdeaux and Dax, in the south of France, but that it changes its aspect greatly on the flanks of the Pyrenees, "where its identity can only be established by the similarity of its fossil remains." According to the same author, the cretaceous rocks of the Pyrenees and Spain present us with compact and crystalline marbles, masses of gypsum and salt, puddingstones, red sandstone, thin shales and grits, containing impressions of marine plants; and other rocks, to which there is nothing analogons in formations of the same age in northern Europe.

There is one extensive development of the cretaceous system in the Morea, composed of compact and lithographic limestone of great thickness, also granular limestone with jasper, and in some districts a conglomerate more than 1600 feet in thickness. It is evident, therefore, from these facts that though a very considerable uniformity is observable in the cretaceous deposits of England and France, very different conditions characterize it in other places; and that, in order to identify the deposits, we must have recourse to the organic remains imbedded in them.

The greensand consists, as already mentioned, of the upper greensand, the gault, and the lower greensand. The term greensand is applied to it from many of its beds consisting of sands of a greenish colour, arising from the presence of green particles of the silicate of iron. "In some places, the upper greensand consists of a soft marly sand, traversed in every direction by stem-like cylinders, having within them cores of darker green matter; it also contains some irregular masses of a bright brown or orange hue; but the greater part is composed of gray calcareous marl resembling the lowest chalk, but so thickly interspersed with green particles as entirely to assume their colour. The green particles, according to analysis, consist of silica, 48·5; black oxide of iron, 22·0; alumina, 17; magnesia, 3·8; water, 7·0; a trace of potash.

In the upper greensand near Godstone, and other places, there are several beds called firestone, which are extensively quarried between that place and Ryegate, chiefly for the purpose of lining furnaces, or for stones used in building under water. Firestone is a uniform fine-grained conglomerate or sandstone, effervescing strongly with acids, and easily cut into any desired form. It contains numerous minute scales of mica and dark particles, scarcely perceptible without a lens. The beds vary from ten to twenty inches in thickness, and are four in number.—The following are the measurements of a section of the firestone pits near Godstone:—

Hard roof, of the same nature as the firestone.

	ft.	in.
1st. Green bed (firestone),................	1	3
Parting,...............................	1	9
2d. Green bed,.........................	1	4
Parting,...............................	0	0
3d. Green bed,.........................	0	10
Flints,................................	0	4
4th. Green bed,........................	0	10

The thickness of the upper greensand is exceedingly variable: at Folkstone it does not exceed thirty feet; in Western Sussex, it measures between seventy and eighty feet; at Blackdown, about one hundred feet; while at Cambridge, it is not more than eighteen inches.

The *gault* is a provincial term for a stiff marly clay, interposed between the upper and the lower greensand. It rarely exceeds 100 feet in thickness, though in some parts of Sussex it is said to be not less than 250 feet. In the Isle of Wight it is about 70 feet; but in West Norfolk it is not more than 15 feet thick. It forms an exceedingly fertile soil, being a mixture of pure clay and calcareous earth. It abounds in fossil remains of great beauty, the pearly lustre of the shells being in many instances preserved. The gault may in general be regarded as composed of two portions; the upper, succeeding the lower greensand, contains green particles, and hence for some feet it is harsh and sandy. The lower portion consists of a smooth uniform very plastic clay of a light-bluish colour, which is used for tiles and common pottery. The lower part contains concretions of iron pyrites, and other nodular and irregular masses.

The lower greensand is divisible into three groups; the uppermost of which consists of white yellowish or ferruginous sand, with concretions of limestone and chert. It commonly forms a flat, but sometimes an irregularly hilly surface, rising from the valley of the gault—it bears a dry barren soil. The second group contains an abundance of green matter, and comparatively little stone. It is retentive of moisture, and occupies a flat marshy tract. The third and lowest group contains more calcareous matter than the upper divisions. Where the sand of the first division emerges from beneath the gault, it is often loose and of a white or buff colour; and passes rapidly from the consistency of loose dry sand to a tough cohesive mass. At the very lowest part, it is sometimes very marly. The fullers' earth belongs to this portion of the series, or to the upper part of the lowest division. The lower part of the latter is usually a group of stone beds, separated by yellowish calcareous sand and clay, commonly called hassock. The whole thickness of the lower greensand, on the shore between Cape Point and Hythe, is about 250 feet; in some places it is much less.

The occurrence of flint nodules in the chalk formation has led to many conjectures as to their origin. Flint, it is well known, is entirely composed of siliceous earth, and chalk of the carbonate of lime, two substances essentially distinct from each other. The flints found in chalk occur at irregular distances from each other, and are of various sizes, and of very irregular forms. They very often enclose a nucleus of sponge or some other zoophyte. Dr Buckland supposes the siliceous matter contained in the cretaceous ocean to have been derived from hot springs, holding it in solution, and that the stronger alcyonia, &c., formed centres of attraction and aggregation to the siliceous matter. He adds further, "it does not appear possible that flints could have been formed by infiltration into pre-existing centres like the regularly disseminated geodes of the trap rocks. Assuming that the mass which is now separated into beds of chalk and flint, was previously to its consolidation, a compound pulpy fluid, and that the organic bodies now enveloped in the strata, were lodged in the matter of the rock, before the separation of its calcareous from its siliceous ingredients, the bodies thus dispersed throughout the mass would afford nuclei to which the flint, in separating from the chalk, would, upon the principle of chemical affinity have a tendency to attach itself. The chalk and flint proceeded through a contemporaneous process of consolidation, the separation of the siliceous from the calcareous ingredients having been modified by attractions which drew to certain centres the particles of the siliceous nodules as they were in the act of separation from the original compound mass. The distances of the siliceous strata must have been regulated by the intervals of precipitation of the matter from which they are derived; each new mass, as it was discharged, forming a bed of pulpy fluid at the bottom of their existing ocean, which, being more recent

than the bed produced by the last preceding precipitate, would rest upon it as a foundation similar in substance to itself, but of which the consolidation was sufficiently advanced to prevent the ingredients of the last deposit from penetrating or disturbing the productions of that which preceded it.

The following observations of Dr Mantell, are still more to the purpose. The white chalk is composed of lime and carbonic acid, and may have been precipitated from water holding lime in solution, from which an excess of carbonic acid was expelled. But some masses of chalk are composed of minute corals and shells, and whole layers in many quarries are formed of the ossicula of star-fishes and other radiaria. The nodules and veins of flints which occur in the chalk, show that water holding silex in solution must have been very abundant at the cretaceous period. The power possessed by thermal waters, of dissolving siliceous earth, depositing flint, and occasioning the silicification of vegetable substances, is strikingly exemplified in the Geysers or hot fountains of Iceland. The perfect fluidity of the silex, before consolidation, is shown by the sharp impressions which the flints bear of shells and other marine bodies and upon breaking the nodules, sponges, alcyonia, and other organic remains will be found enveloped, the siliceous matter having so penetrated the delicate structure of the original, that polished sections display the minute organization of the enclosed zoophytes.

Organic remains.—The fossils of the chalk and greensand are exceedingly numerous, amounting to nearly 800 species, and many are peculiar to the particular division of the series to which they belong. The fossil shells in the chalk are in general exceedingly well preserved. The cavities are frequently filled with flint, sulphuret of iron, or crystals of calcareous spar. The sponges and other soft zoophytes are solidified and the bones of animals and the shelly coverings of crustaceans are often stained with the sulphuret of iron. The teeth and scales of fishes are highly polished. The greensand fossils are generally converted into chert or flint, or chalcedony.

The plants are rare, and where they occur in any quantity consist of sea weeds. Sponges and corals are exceedingly abundant.

Stems of Crinoidia are met with in the chalk; and a variety called the Marsapite is peculiar to it.

Remarkably fine impressions of Asteriæ, or star-fishes, have been found in flint nodules, and in the whitestone of Devonshire. Enchinites are peculiarly plentiful, and are often of great beauty. The Enchinites or Sea Urchins are found in great abundance in some places of our own coasts. Their spherical shell or skeleton is made up of polygonal plates closely fitted into each other, and the surface is divided vertically by bands, like the meridians of a globe, having rows of double perforations. They are studded over with papillæ, which vary in size from mere granular points to large well defined tubercles. Their spines also present great variety of figure and decoration. These were instruments of motion, but as, on the death of the animal, the tendons by which the spines were attached must have been speedily decomposed, the extreme rarity of fossil specimens with these processes affixed is readily explained. The varieties found fossil in the chalk are numerous: the most common are the heart-shaped, the helmet-shaped, the Cideris, and the Nucleolites.

The shells in the chalk are very numerous. The bivalves consist of oysters, scallops and other well-known genera. The genus terebratula is exceedingly abundant, and musters above 50 species; but that class of Mollusca, for which the organic remains of the chalk formation are most remarkable, is that of the Cephalopa. The remains of this interesting class of animals present many features of high interest to the student of natural history; and their beautiful forms and configuration no less render them objects of curiosity to the mere admirer of symmetry and beauty.

The Nautilus of the present seas is a cephalopod, whose shell somewhat illustrates the office which the beautiful organic remains known under the name of Ammonites, Scaphites, Hamites, Sarrelites, &c., were destined to perform in the economy of the animal to which they belonged. These remains, like the shell of the Nautilus, consist of many chambers or cells, perforated by a pipe or syphoncle, by means of which a vacuum can be created, or the density of the air above the animal augmented at will. They acted, in fact, as floats. The animals of the Nautilus reside in the outer chamber of the shell, but as the Ammonites have no enlargement of the outer chamber, it is supposed that they were contained in a fleshy sac, like the similarly constructed shell of the Spirula, one of the inhabitants of the present ocean, and the only true representative of a vast number of extinct forms which existed on the ancient seas.

Nearly 300 species of Ammonites are known, as belonging to the secondary formation. They vary in size from a few lines to 14 feet in diameter.

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MATHEMATICS.

PRINCIPLES OF ALGEBRA

Chapter IV.—Fractions.

34. The rules already established for the management of arithmetical fractions, apply equally to those of algebra: the principles involved and the modes of operation are precisely the same in both. Thus, when a and b are whole numbers, the fraction $\frac{a}{b}$ is the symbol for the quantity which results, when the unit is divided into b equal parts and a of them taken; or when a is divided into b equal parts and one of them taken, just as $\frac{5}{6}$ is the symbol for the sixth part of 1 taken 5 times, and the sixth part of 5 taken once; and when a and b are themselves individually fractions, the fraction $\frac{a}{b}$ admits of the same explanation as $\frac{\frac{2}{3}}{\frac{4}{5}}$ which is simply $\frac{2}{3} \div \frac{4}{5}$. Generally then, every fraction, whether expressed by arithmetical or by algebraical symbols, may be regarded as the quotient resulting from the division of the numerator by the denominator, so that the product $\frac{a}{b} \times b$ is the numerator a. And, conversely, we may regard every division as a process by which we endeavour to find out whether a given fraction can be represented by a simple expression without fractions.

35. The fundamental principle of all our operations upon fractions is this: whatever m is, $\frac{a}{b} = \frac{m\,a}{m\,b}$; that is, by performing the same operation upon both numbers, we do not change the value of the fraction. From this it directly follows:—

1st. If the same factor be found in both members, it may be expunged, and the fraction thereby reduced to lower terms.

$$\text{Thus } \frac{4axxy}{6aaxy} = \frac{2axy \cdot 2x}{2axy \cdot 3a} = \frac{2x}{3a} \text{ and } \frac{axx}{ax+xx} = \frac{x \cdot ax}{x(a+x)} = \frac{ax}{a+x}$$

2d. The terms of any fraction may be both multiplied by the same quantity, and the fraction thereby reduced to an equivalent fraction having for denominator any multiple of the original denominator.

$$\text{Thus } \frac{a}{x} = \frac{a(a-x)}{x(a-x)} = \frac{aa-ax}{ax-xx} = \frac{av}{xv} = \frac{100a}{100x} = \text{\&c.}$$

$$\frac{1}{a-v} = \frac{a}{aa-av} = \frac{a+1}{(a-v)(a+1)} = \frac{1 \times \frac{1}{2}}{\frac{1}{2}(a-v)} = \frac{10}{10a-10v} = \text{\&c.}$$

On this principle, an expression consisting of an integral part and a fraction, may be made to consist of fractional terms only, having the same denominators, by performing the inverse operations of multiplication and division upon the integral part, by means of the denominator of the fractional part; thus,

$$a + \frac{b}{c} = \frac{a\,c}{c} + \frac{b}{c} \qquad \frac{b}{x} - y = \frac{b}{x} - \frac{x\,y}{x}.$$

35. Any number of fractions being given, the numerator and denominator of each may be multiplied by the denominators of all the others, or by a multiple of them, and the given fractions thereby be reduced to equivalent fractions having the same or a *common* denominator: thus, if we take the fractions $\frac{a}{b}, \frac{b}{c}, \frac{c}{d}$, and multiply the terms of $\frac{a}{b}$ by $c\,d$; those of $\frac{b}{c}$ by $b\,d$; and those of $\frac{c}{d}$ by $b\,c$, there results

$$\frac{a}{b} = \frac{a\,c\,d}{b\,c\,d} \qquad \frac{b}{c} = \frac{b\,b\,d}{b\,c\,d} \qquad \frac{c}{d} = \frac{b\,c\,c}{b\,c\,d}.$$

Should the denominators of the given fractions contain among them a repetition of the same prime factor, such prime factor may be taken only once in reducing the fractions to others having a common denominator. Thus $\frac{a}{b\,x}$, and $\frac{b}{a\,x}$, treated as above, become $\frac{a\,d\,x}{b\,d\,x\,x}$ and $\frac{b\,b\,x}{b\,d\,x\,x}$, but these fractions are manifestly reducible to $\frac{a\,a}{b\,d\,x}$ and $\frac{b\,b}{b\,d\,x}$, the prime factors of the given denominators being b, d, x.

36. *Addition and Subtraction.*—What is $\frac{a}{b} + \frac{c}{d}$ and $\frac{a}{b} - \frac{c}{d}$?

Let p and q be the values of the fractions $\frac{a}{b}$ and $\frac{c}{d}$ so that $\frac{a}{b} = p$ and $\frac{c}{d} = q$, then, by the nature of division, $a = b\,p$, and $c = d\,q$.

Now, let each of the equal quantities, forming these equations, be multiplied respectively by d and b, so that $a = b\,p$ becomes $a\,d = b\,d\,p$, and $c = d\,q$ becomes $b\,c = b\,d\,q$; then, combining the results, we obtain

$$\overset{\text{By addition.}}{a\,d + b\,c = b\,d\,p + b\,d\,q}, \qquad \overset{\text{By subtraction.}}{a\,d - b\,c = b\,d\,p - b\,d\,q}.$$

And, dividing both sides of these equations by $b\,d$, we obtain

$$\frac{a\,d + b\,c}{b\,d} = p + q \qquad \frac{a\,d - b\,c}{b\,d} = p - q$$

If we now put for p and q their values $\frac{a}{b}$ and $\frac{c}{d}$, we get

$$\frac{a\,d + b\,c}{b\,d} = \frac{a}{b} + \frac{c}{d} \qquad \frac{a\,d - b\,c}{b\,d} = \frac{a}{b} - \frac{c}{d}.$$

But $\frac{a}{b} = \frac{a\,d}{b\,d}$ and $\frac{c}{d} = \frac{b\,c}{b\,d}$; hence, we conclude that

$$\frac{a}{b} + \frac{c}{d} = \frac{a\,d}{b\,d} + \frac{bc}{bd} = \frac{ad+bc}{b\,d} \text{ and } \frac{a}{b} - \frac{c}{d} = \frac{ad}{bd} - \frac{bc}{bd} = \frac{ad-bc}{bd}.$$

From these formulæ it therefore appears that, the fractions being reduced to a common denominator, their ${}^{\text{sum}}_{\text{difference}}$ has the ${}^{\text{sum}}_{\text{difference}}$ for its numerator, and the common denominator for its denominator; and this agrees with the arithmetical rules.

The preceding mode of establishing a principle, is a simple case of that very frequently resorted to in algebraical investigations, and should be carefully studied by the learner. The following examples will afford him some practice:—

$$\frac{1}{x} + \frac{1}{y} = \frac{y}{xy} + \frac{x}{xy} = \frac{x+y}{xy} \quad \Big| \quad \frac{x}{y} - \frac{y}{x} = \frac{xx}{xy} - \frac{yy}{xy} = \frac{(x+y)(x-y)}{xy}$$

If an integral quantity be joined with a fraction, it is to be considered as a fraction whose denominator is 1, and treated accordingly. The following are mixed quantities:—

$$1 + \frac{a\,a}{a+b} + \frac{b}{a} = \frac{a\,(a+b)}{a\,(a+b)} + \frac{a\,a\,a}{a\,(a+b)} + \frac{b\,(a+b)}{a\,(a+b)}.$$

$$= \frac{a\,a\,a + a\,a + 2\,a\,b + b\,b}{a\,(a+b)}$$

$$2 - \frac{x-1}{x+1} = \frac{x+3}{x+1} \qquad a - x + \frac{a\,a - a\,x}{x} = \frac{a\,a - x\,x}{x}.$$

37. *Multiplication.*—What is the product of $\frac{a}{b}$ by m? Let p be the value of the fraction $\frac{a}{b}$, so that $\frac{a}{b} = p$; then by the nature of division, $a = b\,p$; multiplying these equal quantities by m, we obtain $m.a = m\,b.p$; and, dividing the result by b, we find

$$\frac{m.a}{b} = m.p, \text{ which is } \frac{m.a}{b} = m.\frac{a}{b}$$

for $p = \frac{a}{b}$. From this it appears, that to multiply a fraction by any quantity is to multiply its numerator by that quantity. For example,

$$c \times \frac{a-1}{a+b} \text{ is } \frac{a\,c - c}{a+b}, \text{ and } (a+x) \times \frac{v}{x+y} \text{ is } \frac{a\,v + v\,x}{x+y}.$$

When fractions are written side by side of integral quantities, (and as we shall hereafter see, of each other,) multiplication is intended to be denoted;

Thus, $a\frac{b}{c}$ means $a \times \frac{b}{c} = \frac{a\,b}{c}$

and $(a - c)\frac{x}{y}$ means $(a - c) \times \frac{x}{y} = \frac{(a-c)\,x}{y}$.

Show that $(a - c)\frac{x}{y} - (b + c)\frac{y}{x} = \frac{a\,x\,x + b\,y\,y - c\,(x\,x + y\,y)}{x\,y}$.

38. Let the fraction be $\frac{a}{m\,b}$, and let its numerator be multiplied by m; the result is $\frac{m\,a}{m\,b}$, which is $\frac{a}{b}$.

Therefore, $m \times \frac{a}{m\,b}$, which is $\frac{m \times a}{m\,b}$ is the same as $\frac{a}{m\,b \div m}$.

That is, the result is the same whether the numerator of the fraction be multiplied by the given multiplier, or the denominator be divided by it.

Thus, $a\left(\frac{a-1}{a-a\,b}\right) = \frac{a\,(a-1)}{a - a\,b} = \frac{a-1}{(a-a\,b) \div a} = \frac{a-1}{1-b}$.

So $(a+b)\left(\frac{x+2}{a\,a - b\,b}\right) = \frac{x+2}{x+b}$, and $(x+y)\frac{a-x}{ax+ay} = \frac{a-x}{a}$.

39. Let p be the value of the fraction $\frac{a}{b}$, and let p be multiplied by m, which gives $m.p$; but $m.p = p.m$; therefore $m.\frac{a}{b} = \frac{a}{b}.m$; but $m.\frac{a}{b} = \frac{m\,a}{b}$, consequently, $\frac{a}{b}.m$ is also $\frac{m\,a}{b}$. Or, the rules for the multiplication of a fraction by a whole number, and of a whole number by a fraction, are in effect the same; that is,

a times $\frac{a-1}{x+1}$ is the same as $\frac{a-1}{x+1}$ times a; both give $\frac{a\,a - a}{x+1}$;

$a + x$ times $\frac{a-x}{a+x}$ is $\frac{a-x}{a+x}$ times $a + x$; both give $a - x$.

40. By the preceding reasoning, it appears that the fraction $\frac{m\,a}{b}$ may be either $m.\frac{a}{b}$, or $a.\frac{m}{b}$, or $a.\frac{1}{b}\,m$, or $m\,a \div b$; we therefore conclude, generally, that multiplication and division may be changed in the order of their operation.

Hence $\frac{a+1}{b-a}\,(c-1)$ is $(a+1)\,\frac{c-1}{b-a}$, and may also be written $(a+1)\,(c-1)\,\frac{1}{b-a}$.

41. What is $\frac{a}{b} \times \frac{c}{d}$? Assume $p = \frac{a}{b}$ and $q = \frac{c}{d}$, and multiply $p = \frac{a}{b}$ by b, and $q = \frac{c}{d}$ by d; the results are $b\ p = a$, and $d\ q = c$. Now, the product of equal quantities must be equal quantities; therefore $b\ p \cdot d\ q = a \cdot c$, and dividing these equal quantities by $b\ d$, we obtain

$$p\,q = \frac{a\,c}{b\,d}, \text{ that is } \frac{a}{b} \times \frac{c}{d} = \frac{a\,c}{b\,d}.$$

Hence we conclude that the product of two fractions is a fraction having for its numerator the product of the numerators, and for denominator that of the denominators. And, as the product of any two fractions may be multiplied by a third fraction, and the result again by a fourth, and so on, this rule may be considered as generally applicable to any number of fractions.

$$\text{Thus, } \frac{a}{b} \times \frac{m}{n} \times \frac{p}{q} \times \frac{x}{y} = \frac{a\,m\,p\,x}{b\,n\,q\,y} \qquad \frac{m}{a\,n} \times \frac{3\,b\,n}{2\,m} \times v = \frac{3\,b\,m\,n\,v}{2\,a\,m\,n}$$

$$\left(\frac{2}{a+b}\right)\left(\frac{a-b}{7}\right) = \frac{2\,a - 2\,b}{7\,a + 7\,b} \qquad \frac{a}{b}\left(\frac{a}{b} - \frac{b}{c}\right) = \frac{a\,a\,c - a\,b\,b}{b\,b\,c}$$

The process is often shortened by suppressing, previous to performing the multiplication, all quantities common to the numerators and denominators of the given fractions;

$$\text{Thus, } \frac{a}{y} \times \frac{x}{y} \times \frac{b}{x} \times \frac{y}{c\,x} - \frac{a}{1} \times \frac{1}{y} \times \frac{b}{x} \times \frac{1}{c} = \frac{a\,b}{c\,x\,y}.$$

$$\left(\frac{a+b}{a-b}\right)\left(\frac{a-b}{a+b}\right) = 1 \qquad t\left(\frac{a-x}{m}\right)\left(\frac{1}{a-x}\right) = \frac{t}{m}.$$

42. Observe, that when a fraction has the sign — prefixed, the meaning is that the whole result of the fraction is to be subtracted. When the denominator is removed, it must therefore be remembered that the sign which was placed before the complete fraction now belongs to the complete numerator. When the numerator consists of several terms—the only case in which error can arise—it is generally advisable to place it within brackets until the operation of subtraction has been actually effected. The following example will show what is meant :—

$$\text{Multiply } \frac{3\,x - 1}{4} - \frac{a - x}{5} - \frac{2\,x - 2\,a}{3} - \frac{x\,x + b - c}{8} \text{ by } 120.$$

The operation may be performed as follows :—

$$\frac{120}{4}(3x-1) - \frac{120}{5}(a-x) - \frac{120}{3}(2x-2a) - \frac{120}{8}(x\,x+b-c)$$

that is, $30\ (3\ x-1) - 24(a-x) - 40\ (2\ x - 2\ a) - 15\ (x\,x + b - c)$

or $\quad 90\,x - 30 - 24\,a + 24\,x - 80\,x + 80\,a - 15\,xx - 15\,b + 15\,c$

and by reduction, $56\,a - 15\,b + 15\,c + 34\,x - 15\,xx - 30$.

43. *Division.*—What is $\frac{a}{b} \div c$? Let the dividend and divisor be multiplied by b, which gives $a \div b\,c$; that is $\frac{a}{b\,c}$, which is the same as $\frac{a \div c}{b}$

$$\text{Therefore } \frac{a}{b} \div c \text{ which may be written } \frac{\frac{a}{b}}{c} \text{ is } \frac{a}{b \times c} \text{ or } \frac{a \div c}{b}$$

Hence to divide a fraction by any quantity : Multiply its denominator by that quantity and retain the numerator, or divide its numerator by that quantity and retain its denominator. These rules are the inverse of Arts. 37 and 38, and are exemplified by the following cases :—

$$\frac{a}{x} \div (x+1) = \frac{x}{x\,x + x} \qquad \frac{a+2}{x-a} \div (x+a) = \frac{a+2}{x\,x - a\,a}$$

$$\frac{a\,a - x\,x}{x - v} \div (a+x) = \frac{(a\,a - x\,x) \div (a+x)}{x - v} = \frac{a - x}{x - v}$$

Common factors may be expunged from the numerator and denominator as in the preceding rules;

$$\text{Thus } \frac{9\,a\,b}{10\,c\,d} \div 3\,a\,b\,c = \frac{9\,a\,b}{10\,c\,d \cdot 3\,a\,b\,c} = \frac{9\,a\,b \div 3\,ab}{10\,c\,d \cdot c} = \frac{3}{10\,c\,c\,d}.$$

44. What is $\frac{a}{b} \div \frac{c}{d}$? Multiply the dividend and divisor both by $b\,d$, and we obtain $b\,d \cdot \frac{a}{b} \div b\,d \cdot \frac{c}{d}$, and by reduction $a\,d \div b\,c$, which means $\frac{ad}{bc}$. But $\frac{ad}{bc}$ is the product $\frac{a}{b} \times \frac{d}{c}$, and from this we conclude that

$$\frac{a}{b} \div \frac{c}{d} \text{ means } \frac{a}{b} \times \frac{d}{c} \text{ which is } \frac{a\,d}{b\,c}.$$

To divide therefore by a fraction, is the same as to multiply by the fraction inverted.

Definition.—The quotient of 1 divided by any quantity is called the *reciprocal* of that quantity. Thus $\frac{1}{a}$ is the reciprocal of a and $1 \div \frac{a}{b} = 1 \times \frac{b}{a} = \frac{b}{a}$ is the reciprocal of $\frac{a}{b}$. But $\frac{1}{a}$ and $\frac{b}{a}$ result from $\frac{a}{1}$ and $\frac{a}{b}$ by inversion of the terms; and as integral quantities may be regarded as fractions having 1 for denominator, we conclude generally that the reciprocal of any quantity is a fraction formed by inverting the terms of the proposed fraction. Hence from this and the preceding rule, it follows, that to divide by any quantity is the same as to multiply by its reciprocal, and *vice versâ.* Thus $a \div b$ is $a \times \frac{1}{b}$ and $a \div \frac{1}{b}$ is $a \times b$.

$$\frac{p}{q} \times a \text{ or } a \times \frac{p}{q} \text{ is } a \div \frac{q}{p}$$

$$a \div \frac{p}{q} \text{ is } a \times \frac{q}{p} \text{ or } \frac{q}{p} \times a.$$

From the definition it also follows that the product of any quantity multiplied by its reciprocal must be 1;

$$\text{Thus } \frac{3}{4} \times \frac{4}{3} = \frac{12}{12} = 1 \text{ and } \frac{a}{b} \times \frac{b}{a} = \frac{a\,b}{a\,b} = 1.$$

The following are examples of the application of the rule :—

$$\left(\frac{a}{b} + \frac{b}{a}\right) \div \frac{a}{b} = \left(\frac{a}{b} + \frac{b}{a}\right) \times \frac{b}{a} = 1 + \frac{a\,b}{a\,a}$$

$$\frac{\frac{a}{b}}{\frac{x}{y}} \text{ means } \frac{a}{b} \div \frac{x}{y} = \frac{a\,y}{b\,x} \qquad \frac{\left(\frac{axx}{by}\right)}{\left(\frac{cxx}{dyy}\right)} \text{ is } \frac{axx}{by} \div \frac{cxx}{dyy} = \frac{ady}{b\,c}$$

$$\frac{\left(\frac{a+b}{2}\right)}{\left(\frac{a-b}{2}\right)} = \frac{2(a+b)}{2(a-b)} = \frac{a+b}{a-b} \qquad \frac{\left(\frac{a}{q}\right)}{\left(\frac{p}{q}\right)} \div \frac{\left(\frac{x}{y}\right)}{\left(\frac{m}{n}\right)} = \frac{\frac{a}{b}}{\frac{p}{q}} \times \frac{\frac{m}{n}}{\frac{x}{y}} = \frac{amqy}{mnxy}$$

$$\left(\frac{m}{n} - \frac{x}{y}\right) \div \left(\frac{p}{q} - \frac{a}{b}\right) = \frac{my - nx}{ny} \times \frac{bq}{bp - aq} = \frac{bmqy - bnqy}{bnpy - anqy}.$$

It must not be supposed that in cases of this sort it would be enough to multiply the dividend by the reciprocals of the individual fractions of the divisors : we must multiply by the reciprocal of the *whole* divisor, and the reciprocal of $\frac{p}{q} - \frac{a}{b}$ is not $\frac{q}{p} - \frac{b}{a}$ but $\frac{b\,q}{b\,p - a\,q}$ as may be shown thus : The reciprocal by definition is $1 \div \left(\frac{p}{q} - \frac{a}{b}\right)$. Multiply both divisor and dividend by $b\,q$, the least common multiple of b and q, and this becomes $b\,q \div (b\,p - a\,q)$ which is $\frac{b\,q}{b\,p - a\,q}$ as announced. When however the divisor consists of several fractions the reduction is

more readily effected by the following method, which is deduced immediately from the proposition $\frac{a}{b}=\frac{m\,a}{m\,b}$ and the notation of division.

$$\left(\frac{m}{n}-\frac{x}{y}\right)\div\left(\frac{p}{q}-\frac{a}{b}\right)=b\,n\,q\,y\left(\frac{m}{n}-\frac{x}{y}\right)\div b\,n\,q\,y\left(\frac{p}{q}-\frac{a}{b}\right)$$

$$\text{or}\quad .\ .\ .\ .\ .\ =\frac{\frac{m}{n}-\frac{x}{y}}{\frac{p}{q}-\frac{a}{b}}=\frac{\left(\frac{m}{n}-\frac{x}{y}\right)bnqy}{\left(\frac{p}{q}-\frac{a}{b}\right)bnqy}=\frac{bmqy-bnqy}{bnqy-anqy}$$

The multiplier $b\,n\,q\,y$, it will be observed, is the least common multiple of the denominators of the fractions composing the dividend and divisor. The following are examples of the same kind :—

$$\frac{\frac{a}{b}-\frac{c}{d}}{\frac{a}{d}+\frac{b}{c}}=\frac{\left(\frac{a}{b}-\frac{c}{d}\right)b\,c\,d}{\left(\frac{a}{d}+\frac{b}{c}\right)b\,c\,d}=\frac{a\,c\,d-b\,c\,c}{a\,b\,c+b\,b\,d}\qquad\frac{\frac{x}{y}+1}{1-\frac{y}{x}}=\frac{x\,x+x\,y}{x\,y-y}$$

$$\frac{\frac{1}{1+x}-x}{1-\frac{x}{1+x}}=\frac{\left(\frac{1}{1+x}-x\right)\left(1+x\right)}{\left(1-\frac{x}{1+x}\right)\left(1+x\right)}=\frac{\frac{1+x}{1+x}-(1+x)x}{1+x-\frac{(1+x)x}{1+x}}=1-x(1+x)$$

$$\frac{\frac{1}{1+x}}{1-\frac{1}{1+x}}=\frac{1}{x}\qquad\frac{\frac{1}{1+x}+\frac{x}{1-x}}{\frac{1}{1-x}-\frac{x}{1+x}}=1.$$

45. All these formulæ are true, whether the letters used represent fractions, or are removed, and fractions substituted for them.

Example 1.—To prove the formulæ, $(m+n)\,a=a\,m+a\,n$ when m, n, a, are respectively the fractions $\frac{p}{q}\,\frac{r}{s}\,\frac{x}{y}$.

$$\text{Here } m+n=\frac{p}{q}+\frac{r}{s}=\frac{p\,s+q\,r}{q\,s}\qquad\text{(Art. 36.)}$$

$$\therefore(m+n)\,a=\left(\frac{p\,s+q\,r}{q\,s}\right)\frac{x}{y}=\frac{(p\,s+q\,r)}{q\,s\,y}=\frac{p\,s\,x+q\,r\,x}{q\,s\,y}$$

Exercise.—Show, by means of the preceding, that the formula $(a+b)\,(a-b)=a\,a-b\,b$ is true when a and b are respectively the fractions $\frac{m}{n}$ and $\frac{p}{q}$

Example 2.—To prove $\frac{a}{b}=\frac{m\,a}{m\,b}$ when a, b, and m, have the same values as in example 1.

$$\frac{a}{b}=\frac{\frac{p}{q}}{\frac{r}{s}}=\frac{p}{q}\div\frac{r}{s}=\frac{p\,s}{p\,s}\qquad\text{(By Art. 44.)}$$

$$m\,a=\frac{x}{y}.\frac{p}{q}=\frac{x\,p}{q\,y}\qquad m\,b=\frac{x}{y}.\frac{r}{s}=\frac{x\,r}{y\,s}$$

$$\therefore\frac{m\,a}{m\,b}=\frac{\frac{x\,p}{y\,q}}{\frac{x\,r}{y\,s}}=\frac{x\,p}{y\,q}\div\frac{x\,r}{y\,s}=\frac{x\,y\,p\,s}{x\,y\,q\,r}$$

$$\text{But }\frac{x\,y\,p\,s}{x\,y\,q\,r}=\frac{x\,x}{x\,y}.\frac{p\,s}{q\,r}=\frac{p\,s}{q\,r}=\frac{p}{q}\div\frac{r}{s}=\frac{\frac{p}{q}}{\frac{r}{s}}=\frac{a}{b}$$

$$\text{Hence }\frac{m\,a}{m\,b}\text{ which is }\frac{\frac{x}{y}\frac{p}{q}}{\frac{x}{y}.\frac{r}{s}}\text{ is }\frac{\frac{p}{q}}{\frac{r}{s}}\text{ which is }\frac{a}{b}$$

For Exercise.—Show, by help of the preceding, that the following formulæ are true when $a=\frac{m}{n}$; $b=\frac{p}{q}$, and $c=\frac{r}{s}$ and $d=\frac{x}{y}$

$$\frac{a}{b}+\frac{c}{d}=\frac{a\,d+b\,c}{b\,d}\qquad\frac{a}{b}\times\frac{c}{d}=\frac{a\,c}{b\,d}$$

$$\frac{a}{b}-\frac{c}{d}=\frac{a\,d-b\,c}{b\,d}\qquad\frac{a}{b}\div\frac{c}{d}=\frac{a\,d}{b\,c}$$

46. *Definition.* When a quantity is multiplied any number of times into itself, it is said to be *involved*, and the process is called *involution.*

Theorem.—Any power of a fraction has the numerator and denominator equally involved;

Thus : What is $x\,x$ when $x=\frac{a}{b}$? Ans. $\frac{a}{b}\cdot\frac{a}{b}=\frac{a\,a}{b\,b}$

Similarly $x\,x\,x=\frac{a\,a\,a}{b\,b\,b}$; $x\,x\,x\,x=\frac{a\,a\,a\,a}{b\,b\,b\,b}$ and so on. But by definition any quantity multiplied into itself is called a *power* of that quantity ; therefore $\frac{a\,a}{b\,b}$, $\frac{a\,a\,a}{b\,b\,b}$, $\frac{a\,a\,a\,a}{b\,b\,b\,b}$, and so on, are powers of $\frac{a}{b}$ and have the numerator a and the denominator b equally involved.

47. Let us now inquire what effect is produced upon the value of a fraction by augmenting or diminishing its two terms by the same number ?

When to the two terms of the fraction

$$\frac{a}{b}=v$$

we add the same number m, the value v of the fraction will be increased or diminished ; let us designate the variation by δ and we have

$$\frac{a+m}{b+m}=v\pm\delta$$

where δ denotes the difference of the two fractions ; but in the mean time we are unable to assign to δ any numerical value ; even its sign is unknown : we therefore write the double sign $\pm$ which means either $+$ or $-$, and is a form frequently employed when we are unable to say whether the quantity is additive or subtractive. Here then we perceive that δ represents a number not only unknown in value, but that value, whatever it may be, stands in an unknown relation to the primitive value v. In order then to find out what this δ really is, let us subtract from these equal quantities the given equal quantities $\frac{a}{b}=v$ and we obtain,

$$\frac{a+m}{b+m}-\frac{a}{b}=\delta\text{ whence }\delta=\frac{b\,(a+m)}{b\,(b+m)}-\frac{a\,(b+m)}{b\,(b+m)}$$

and, making the subtraction here indicated, we obtain

$$\delta=\frac{b\,a+b\,m-a\,b-a\,m}{b\,(b+m)}=\frac{b\,m-a\,m}{b\,(b+m)}=\frac{m\,(b-a)}{b\,(b+m)}$$

and therefore finally

$$\delta=\frac{m}{b}\cdot\frac{b-a}{b+m}$$

Now, between the given numbers a and b, there may exist any of the three relations,

a greater than b; $a=b$; a less than b.

Under the first the difference $b-a$ is a negative quantity divided by the number $b+m$; the quotient must therefore be a negative quantity, and this quotient being repeated $\frac{m}{b}$ times must give a negative product which is the value δ; and consequently our expression ought to have been

$$\frac{a+m}{b+m}=v-\delta$$

Whence we conclude, that the value of a fraction $\frac{a}{b}$ when greater

than 1, is diminished when we add the same number to each of its two terms.

In the second case, the difference δ being 0, we have in effect

$$\frac{a}{b} = \frac{a}{a} = \frac{a+m}{b+m} = \frac{a+m}{a+m} = 1$$

In the third case the difference δ is additive, and this being the case, we conclude that the value of a proper fraction $\frac{a}{b}$ is augmented when we increase each of its two terms by the same quantity. Finally then we may remark that these hypotheses

a greater than b ; $a = b$; a less than b

correspond with $\delta = -$; $\delta = 0$; $\delta = +$
that is to say, the difference δ changes from negative to positive in passing 0.

48. Suppose now that we diminish by the same number m each of the two terms of a given fraction $\frac{a}{b}$ so that it becomes

$$\frac{a-m}{b-m} = v \pm \delta$$

δ having the same meaning as before. We have, in subtracting $\frac{a}{b}$ and v from the respective sides of this equation,

$$\frac{a-m}{b-m} - \frac{a}{b} = \delta \text{ that is } \delta = \frac{b\,(a-m)}{b\,(b-m)} - \frac{a\,(a-m)}{b\,(b-m)}$$

$$\text{whence } \delta = \frac{b\,a - b\,m - b\,a + a\,m}{b\,(b-m)} = \frac{m\,(a-b)}{b\,(b-m)}$$

therefore $\delta = \frac{m}{b} \cdot \frac{a-b}{b-m}$ from the last value.

Let us now suppose

b greater than m, with a greater than b

$a = b$; and a less than b.

and we find, first the difference δ additive, second 0, and third subtractive; which is the inverse of the conclusions arrived at when m was added to the terms of the fraction.

From this, then, we conclude, that when we diminish the two terms of a fraction by *a number which is less than the denominator of the given fraction*, 1st, the value is augmented, when the primitive value of the fraction is greater than 1; 2d, the value is not changed when the value of the given fraction is 1; 3d, the value is diminished if the fraction be less than 1.

Let us take, in the second place,

$b = m$ with a greater than b
$a = b$; and a greater than b.

Directing our attention to the first case in which $b = m$ with a greater than b, then

$$\delta = \frac{m}{b} \cdot \frac{a-b}{b-m} = 1 . \frac{a-b}{0} = \frac{a-b}{0}$$

so that if $a = 3$, and $b = 2$, we obtain the singular result $\delta = \frac{1}{0}$ a result to which we cannot as yet assign any signification, but to which we shall have occasion to refer when we come to treat of equations in one of our subsequent chapters.

If we take $b = m$ with $a = b$, we find $\delta = 1 \times \frac{0}{0} = \frac{0}{0}$, a symbol also to which we are in the mean time unprepared to assign a meaning.

When we take $b = m$ with a greater than b, and make, for example, $a = 2$, and $b = 3$, we find $\delta = -\frac{1}{0}$, a result agreeing with $\delta = \frac{1}{0}$, found above, except in sign.

To conclude the discussion, there still remains for examination the cases of b less than m taken with a greater than b ; $a = b$; a less than b; but these we leave as exercises to the student, who will find little difficulty in following them out from those given.

We are now prepared to enter upon a more interesting part of our subject.

WORSLEY HALL, NEAR MANCHESTER,

THE SEAT OF THE RIGHT HONOURABLE THE EARL OF ELLESMERE.

(Illustrated by a Plate.)

As a beautiful illustration of the mediæval style of architecture, we beg to introduce to our readers, in the present number, an elegant engraving of Worsley Hall, the seat of the Earl of Ellesmere, one of the most princely modern mansions in England. It is a place which is yet but little known to tourists, except in connection with her Majesty's visit to the noble owner in 1851, the foundation-stone of the building having been laid, we believe, in 1840, and the mansion completed in 1846. Although one of the finest productions of modern architectural skill, and occupying also a highly interesting locality, Worsley Hall has not yet been introduced, with that prominence which it merits, into many of our travelling guide-books. The circumstance, however, of its having been honoured with the presence of her Majesty and Prince Albert, on the occasion of the royal visit to Manchester, has given it so deep an interest, that visitors to that manufacturing metropolis—as Manchester may justly be termed—are now impelled by a very natural curiosity to turn aside from the gigantic palaces of cotton, to this magnificent specimen of modern mediæval art. The township of Worsley, in the neighbourhood of which the hall is erected, is seven miles from Manchester, and is about the same distance from Bolton. The building was erected from the designs of Mr. Blore, and is finely placed on an eminence commanding a view of no less than seven counties. On the south, the view ranges across the centre of Cheshire, the conical peak of the Wrekin towering up in solitary grandeur in the distance; on the east, the Derbyshire hills may be distinctly descried; and on the north, the Westmoreland mountains may be seen on a clear day. To the westward is the great field of that manufacturing industry of which Manchester forms the teeming centre, and which, with its busy myriads of population, has latterly exercised so powerful an influence over the destinies of England. On this side is the principal front of the hall; and at some distance, in the same direction, are two of the most interesting triumphs of modern engineering skill—the Bridgewater Canal, and the Manchester and Liverpool Railway—each the first adventurous experiment in those systems of transit which have changed the face of the country within the last few years, and given so prodigious an impulse to manufacturing industry. In anticipation of her Majesty's visit to Worsley, the Earl of Ellesmere had two state barges constructed, and luxuriously fitted up, one of which was occupied by her Majesty on her route from Patricroft to Worsley by the canal, a distance of two miles. Her Majesty, who takes a deep interest in objects of architectural beauty, was much delighted with the Hall, and the extensive view which it commands. The interior of the edifice is not so capacious as might be supposed from the external view, and consists of a larger proportion of bed-rooms than is usual. The panellings of the principal apartments are of oak, and in character with the exterior

Hors[illegible] Hall near Manchester

[illegible]

of the building. In the drawing-room is Landseer's celebrated picture of the "Return from Hawking," in which the artist has skilfully contrived to combine with an historical illustration of the costume and customs of another phase of society, faithful likenesses of the Earl and Countess, and of their family. In the neighbourhood are three curious old halls. One, at the northern extremity of the gardens of the new hall, was the successive residence of the Worsleys, the Masseys, the Stanleys, and the Egertons; it is constructed of brick, wood, and plaster, with pointed gables. Another is a similar building, called Kempnall Hall, said to have been the residence of Nicholas Starkie in 1594, when his family was under the supposed visitation of demoniacal possession; and the third, to the east of the latter, is the ancient pile of Wardley Hall, of the age of Edward VI., standing in the midst of a small woody glade, and originally surrounded by a moat, except on the eastern side. It is of a quadrangular form, consisting of ornamented wood and plaster frames, interlined with bricks, and entered by a covered archway, opening into a court-yard in the centre. This building has lately been repaired by Lord Ellesmere, who, we may add, is a brother of the Duke of Sutherland, and has always been distinguished for his taste, munificence, and eminent abilities, as well as for his extensive fortune.

PORTER'S PATENT ANCHOR AND THE RECENT GOVERNMENT TRIALS AT SHEERNESS.

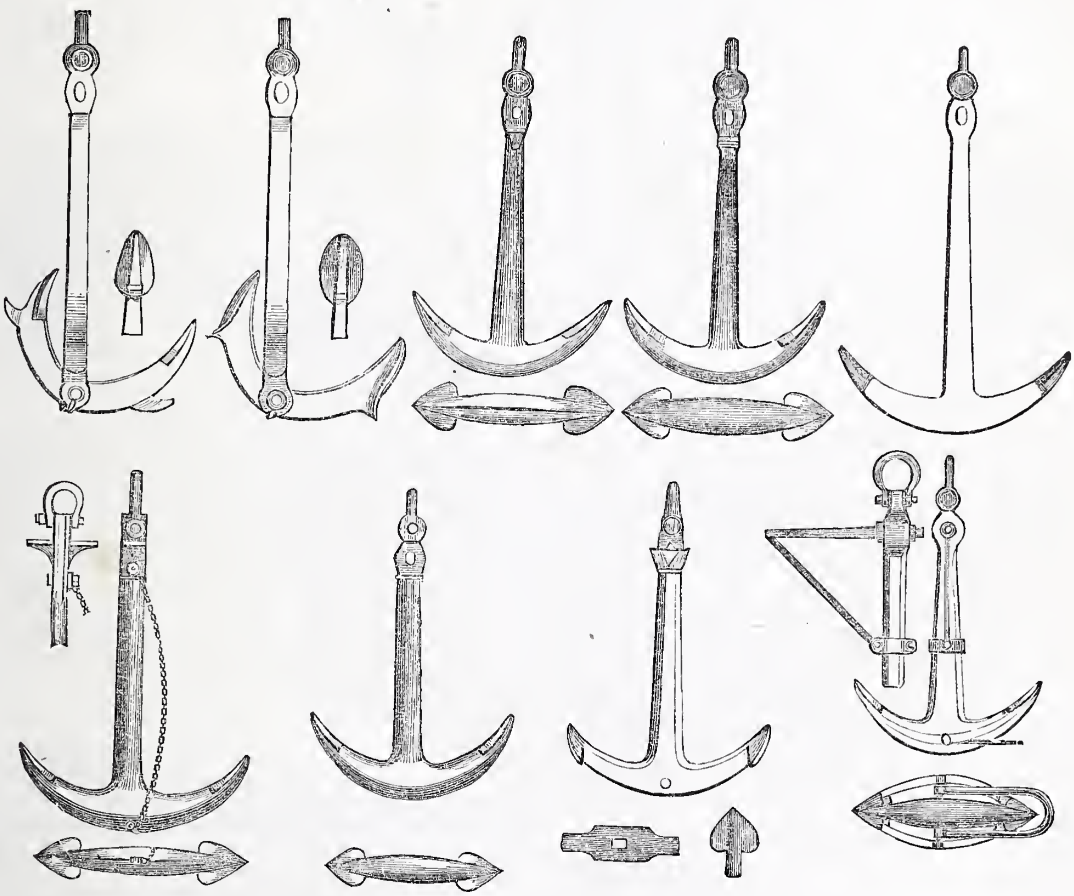


Fig. 1.—Honibal. Fig. 2.—Trotman. Fig 3.—Aylen. Fig. 4.—New Admiralty. Fig. 5.—Rodgers.

Fig. 6.—Mitcheson. Fig. 7.—Lennox. Fig. 8.—Rodgers' Kedge. Fig. 9.—Isaacs.

The pre-eminent excellence of this anchor, as evinced by the Government trials at Sheerness in the autumn of last year (1852), entitle it to a detailed notice, in the course of which we shall take the opportunity of entering, at some length, into the general merits of the subject.

Mr. Honibal is the assignee of Messrs. Porter's patent; but under the same name, because constructed on the same principle, (although with important improvements in details,) may be included Mr. Trotman's, which showed a decided superiority over all its competitors in most of the late Government trials: Mitcheson & Son's was the only anchor which seemed to be of equal excellence in point of holding power. The comparative merits of these two anchors in this important particular is still disputed, although we are inclined, on the whole, to give the pre-eminence to Trotman's. And in other respects the latter has decided advantages, which, if its holding powers were not more than barely equal to those of its numerous rivals, would amply entitle it to the preference. This anchor, on the whole, appears to be decidedly the best that has yet been suggested in theory, or adopted in practice. Mr. Honibal, as we have stated, is the assignee of Porter's patent, and Mr. Trotman, who has brought the anchor to its present perfection, is Mr. Honibal's nephew. It is now in use in 150 men-of-war, and by several steamship companies, but hitherto it has entailed a loss of £15,000 in working the patent. In these circumstances we are glad to learn that the original patent has been extended for six years.

It would be quite inconsistent with our present object to enter at length into the special characteristics of each of the different anchors which were brought into competition with those on Messrs. Porter's principle in the late trials. We shall therefore merely remark, that out of about thirty exhibitors of anchors in the Crystal Palace,

Hyde Park, there were only six who came forward to submit to this searching examination. These were Lieutenant Rodgers; Messrs. Brown, Lennox, & Co.; Mitcheson & Son; Mr. Honibal; Mr. Trotman; and Mr. Isaacs, an American. Against these, in some of the subsequent trials, were pitted also Mr. J. Aylen's and the New Admiralty anchor (Sir William Parker's). That by Messrs. Brown & Lennox differs only slightly from Sir William Parker's plan in section and in length of shank, and in having a palm more spear-shaped. Mr. Isaacs' anchor has an arrangement to prevent fouling. Lieutenant Rodgers had two anchors on trial,—one, his Exhibition prize anchor, and the other, a variety which he designates a stream kedge. We prefix sketches of these nine anchors, from which it will be seen that the two on Messrs. Porter's principle, namely, Mr. Honibal's and Mr. Trotman's, differ essentially from all the others.

The first series of experiments commenced on the 1st of July, at the testing ground, in the dockyard at Sheerness. By the regulations, a fourfold purchase was to be attached to each anchor, the falls to be toggled to a pendant and jewel-block, with one purchase to be brought to a capstan. The proper arrangements being made, Honibal's anchor, total weight, 24 cwt. 3 qrs. 20 lbs., was opposed to Aylen's, of 24 cwt. 2 qrs. 24 lbs. It was found that, at a long scope of cable, Aylen's "came home" (or dragged) 3 feet $7\frac{1}{2}$ inches, Honibal's only 1 foot 6 inches. The position of the gear was then changed, so as to have the effect of a ship riding at short-stay peak, when Aylen's broke out of the ground at 9 feet 7 inches, or at a total distance of 13 feet $2\frac{1}{2}$ inches from first position; Honibal's continued to hold on, and settled only $2\frac{1}{2}$ inches. The superiority of Honibal's (Porter's) to Aylen's, in point of holding power, was thus clearly established. In the next experiment, Mitcheson & Son's anchor was pitted against Mr. Isaacs' (American), and proved to be decidedly superior to the latter, both at long scope and at short-stay peak. The two anchors next tested were Trotman's (improved Porter's) and Lieutenant Rodgers' Exhibition prize anchor; the weight of the former being 25 cwt. 6 lbs., and that of the latter 24 cwt. 2 qrs. 22 lbs., so that Mr. Trotman's had the advantage in weight of rather more than 1 qr. In this experiment Rodgers' drew 5 feet; Trotman's, 3 feet $7\frac{1}{4}$ inches; but the former came out of the ground at 18 feet total distance, while Trotman's, drawing only $2\frac{1}{4}$ inches, held on at 3 feet $9\frac{1}{2}$ inches total distance from first position. Mr. Lennox's anchor was then tested against the Admiralty, to which it was found to be inferior in holding power. The four best anchors were then opposed to each other, namely, Honibal's to Mitcheson's, and Trotman's against the Admiralty. In the first trial, at long scope, Mitcheson's dragged 5 feet 6 inches, Honibal's 4 feet $4\frac{1}{2}$ inches. At short-stay peak, Mitcheson's came out of the ground at 24 feet $4\frac{1}{2}$ inches, Honibal's dragging 6 feet $8\frac{1}{2}$ inches, total distances. Trotman's anchor was then opposed to the Admiralty, when the former, at long scope, drew 6 feet 8 inches, the latter 4 feet $10\frac{1}{2}$ inches, while, at short-stay peak, the Admiralty anchor was forced out of the ground at a total distance of 22 feet 10 inches, Trotman's drawing 9 feet 11 inches, but still holding on.

The competing anchors were now reduced to the two on Messrs. Porter's principle, namely, Honibal's and Trotman's, which had been proved superior to those respectively opposed to them. The trial between these was naturally regarded with profound interest by the jury and the other gentlemen assembled. At long scope, Honibal's drew 5 feet, Trotman's 6 feet 5 inches; but after a most severe contest at short-stay peak, the strain applied being such as to make the blocks and gear crack, Honibal's was ultimately wrenched out of the ground at 16 feet 6 inches total distance, while Trotman's continued to hold on at 10 feet 2 inches.

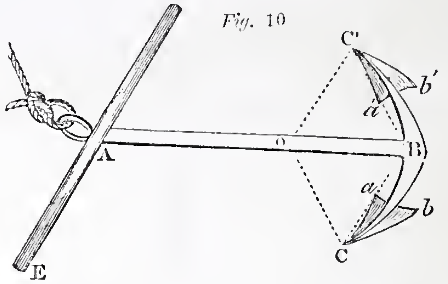
Another trial was then made with Lieutenant Rodgers' stream kedge, pitted against Mr. Trotman's. At long scope, Rodgers' dragged 7 feet $8\frac{1}{2}$ inches; Trotman's, 6 feet. At short-stay peak, Rodgers' was pulled out of the ground at 24 feet 6 inches, Trotman's holding on at 9 feet 1 inch, total distances from first position.

From these trials it appeared that the three best anchors were Trotman's, Honibal's, and Mitcheson & Son's, in the order here stated. It is proper to state, however, that, in a subsequent trial, Mitcheson's brought home Trotman's, although, from the facility with which this very unexpected result was accomplished, it is naturally presumed that the latter had fallen on its stock end, the experiment, in this latter case, having been made on a beach covered with several feet of water. A final experiment is yet wanting to decide, in a perfectly conclusive manner, the comparative holding powers of these two anchors. On the whole, however, we think there are good reasons for believing that Trotman's is superior to the other, even in this important quality, while it has other advantages that give it a decided claim to the preference over all its competitors.

We therefore take Porter's (Honibal's) anchor as the subject of the following details and illustrations, because it includes the distinguishing principle of Trotman's, while, at the same time, it will not encumber us with too many minor details, in explaining to our readers the general theory of the anchor. Mr. Trotman's improvements chiefly consist in imparting a slightly different form to the flukes and toggles, parts of the anchor which we are about to explain, and in other matters which do not essentially alter, while they undoubtedly improve, the anchor of the original patent.

We shall begin by describing the different parts of the common ship anchor, of which a sketch is annexed (fig. 10.) It is composed of four parts, the *ring*, the *shank*, the *arms*, and the *stock*. The ring, to

Fig. 10



which the cable is attached, is fixed on one extremity of the shank, A B, and the arms on the other extremity. These arms B C, B C', consist of the *palms* or *flukes*, and the *bill*; the palms $a\ b\ c$, $a'\ b'\ c'$, are broad plates of a triangular form, at nearly the extremities of the arms; the bills are the sharp points at the extremities of the arms. The *throat* B of the arms is the rounded angle at their junction with the shank; this point of junction is termed the *crown*. A distance equal to the length of one arm from the throat to the bill, is marked on the shank from the crown at O, and is called the *trend*. The *small round* A is the smallest part of the shank near the stock; and the stock is a beam of wood or bar of iron E F, fixed on the extremity of the shank, at right angles to the plane of the arms.

Now, the long standing objections to the common anchor are, that when on the ground, one arm is not only of no avail, but is often mischievous. In shallow water, for example, when the one arm takes the ground, the other presents immediately above it, a dangerous projection, which in crowded anchorages constitutes a hidden peril, which is not unfrequently productive of incalculable injury. Again, of whatever degree of thickness the arms are made, their junction with the shank at the crown, renders it necessary that they shall be welded precisely on the part liable to the greatest strain, which has been the principle cause of so many anchors breaking at this point. These parts being cemented at one place, the work was seldom well executed, owing to the extreme difficulty which the workmen experienced in striking an effective blow on the throat, after the arms and the shank had been brought together. A well made anchor was considered a chef-d'œuvre in forge manufacture, prior to the introduction of forging machinery. In the third place, it may be observed, that common anchors frequently snap at the trend when let go *amain*, to anchor the ship, by falling on hard ground, or on a rock, as must be too well known to every seaman—thus, what ought to be the sailor's chief hope and protection, suddenly and unhappily ceases to render its important aid.

In Messrs Porters' anchor, these difficulties and defects are very happily and in many respects ingeniously avoided, at the same time that the principle of construction is simplified, and additional strength given to the parts. This is very obvious from the following figs. 2, 3, 4, which represent the anchor in various attitudes on the bed of the sea, after having been canted.

To explain the principle of construction, it is to be observed, that the anchor is manufactured in two distinct parts; one forming the arms is made of bars, extending from pea to pea, without any crossing or welding, and the other is the shank. By this arrangement, the fatal risk of an unsound weld at the crown, the part in which the present anchor fails in the hour of peril, is averted. The juncture of these arms to the shank by means of a bolt, which enables them to librate, furnishes a second discriminating property; and the spur, horn, or toggle attached to each of the arms outwardly, is the grand principle on which, for penetration, the action of the arms depends.

Figure 11, shows the position which the anchor assumes when first canted. It rests upon the extreme end of the shank, the stock, and the horn, and naturally falls into this adjustment on

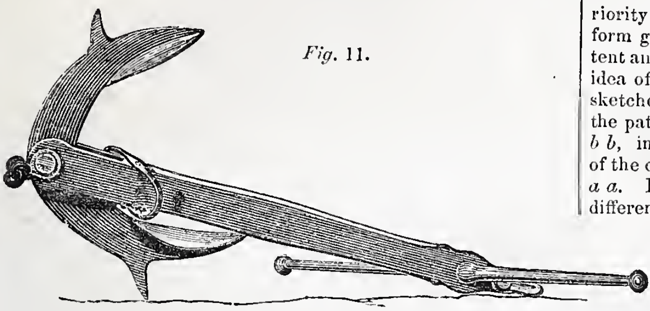


Fig. 11.

account of its form and weight. Here, then, the horn performs the office of a fulcrum; for the strain of the cable will very speedily bring the point of the lower arm also upon the ground, as illustrated by

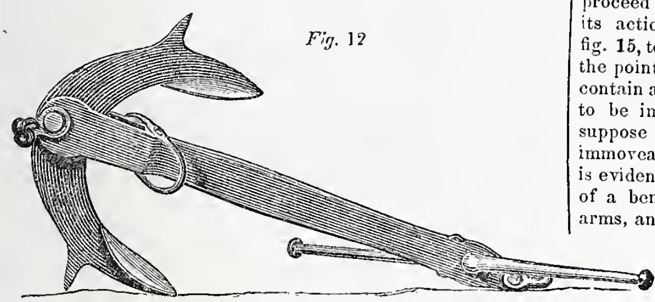


Fig. 12

But the continued strain of the cable upon the anchor pulls it forward still further, causing the tip of the upper fluke to descend and close upon the shank, presenting the appearance exactly of fig. 11 inverted. The anchor has now by these two movements gained the position of penetration; thus the next effect of the strain upon the cable is to cause the lower arm to penetrate until the shank rests upon the sand parallel to and in contact with it, as described in

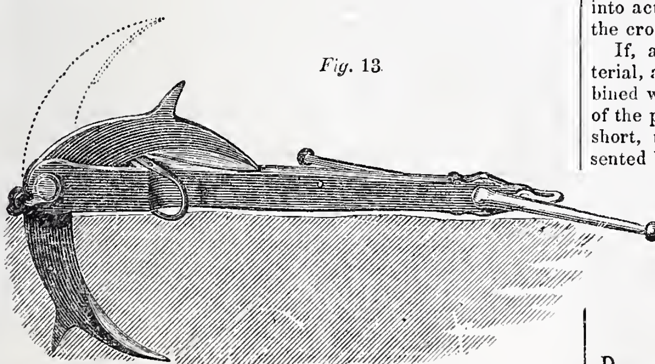


Fig. 13.

By means of the pin, then, which allows the arms to librate freely, the upper fluke is brought close to the shank, and while the strain is operating with full force upon the anchor, the greater portion of the resistance is removed from the throat and hinge, and developed at the trend, or that part of the shank on which the upper pea rests; thus dividing the resistance more equally, and bringing the leverage much nearer the ring. By this arrangement the anchor is qualified to bear those strains and jerks, which are fatal to anchors of the ordinary construction. It therefore appears, that the superiority of Messrs. Porter's anchor consists mainly in the upper arm coming in contact as an arch with the shank.

Among the minor points of superiority there may be noticed, the form given to the flukes of this patent anchor. To convey an accurate idea of this improvement, we have sketched in fig. 14 the form of the patent fluke in the dark lines *b b*, in juxta-position with that of the common fluke in dotted lines *a a*. In order to appreciate the difference in length, it ought to be stated, that the arms of the patent anchor are $\frac{1}{6}$th longer, and the shank $\frac{1}{10}$th shorter than the same parts in the common anchor; and it is easy to perceive that the patent fluke is superior to the other in form also.

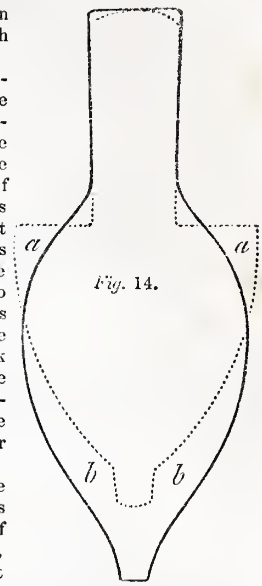
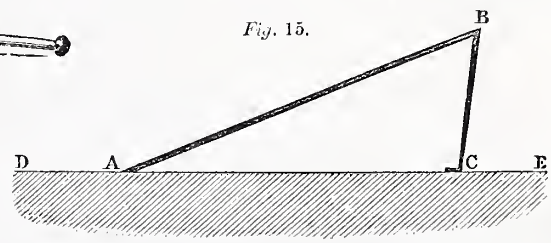


Fig. 14.

To investigate geometrically the principles of the anchor, let us proceed with the simplest idea of its action, and suppose A B C, fig. 15, to be a bar of iron, bent at the point B, in such a manner, that the two parts A B, B C, shall contain an angle at B = 60°, and let D E be the surface supposed to be impenetrable, on which the figure rests. If we further suppose a force A D, acting on the figure at the point A, and an immoveable object resisting that force, acting at the point C, it is evident that the condition of the body, A B C, is similar to that of a bent lever, of which B is the fulcrum, and B A, B C, the arms, and that the tendency of the action and re-action of the

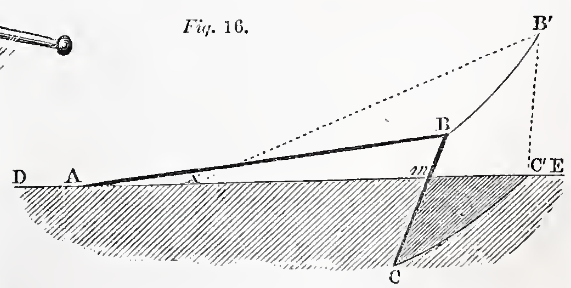
Fig. 15.



forces applied to it, is to unbend the bar A B C, or to break it at B. In the common anchor, then, the forces which are called into action have the greatest tendency to create a rupture at the crown B, or the point of junction of the shank and arms.

If, again, the surface D E, fig. 16, be of some penetrable material, as mud or sand, then the action of the force A D combined with the weight of the anchor A B C, will cause the sinking of the point c into the sand, the obstacle at C′ being removed; in short, the anchor will glide from its original position, represented by the dotted line A′ B′ C′, into the new position A B C, from

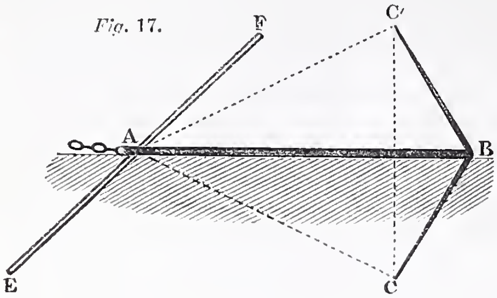
Fig. 16.



which, if it be prevented from passing, the leverage of the resisting medium upon the arm B C will be shortened by half the length *m* C. It is obvious, then, that though the compound effect of the forces acting upon the anchor will not be so great as before, by reason of the diminished leverage upon B C, yet the ultimate tendency is the same as before, to separate the

arms at the point B; and would still be so, were the arm sunk to the crown, as represented in figure 17.

Fig. 17.

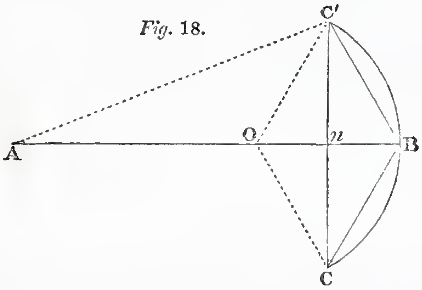


The general inference from these remarks is, that the ordinary effect of the forces which operate on a common anchor, while at the bottom of the sea, tends directly to rupture the parts about the crown.

In the common anchor, fig. 10, the interior contour of the arms C B C′, forms an arc of a circle containing 120°, and the chord or direct length, B C, of each arm, is equal to the radius of the circle, B O, the point O being the trend. But in Messrs. Porter's anchor, the arms are set in two distinct arcs of 60° each, turned on distinct centres in the manner of a gothic arch. This will be explained by reference to the following illustrations.

Let A B, fig. 18, be the shank of the common anchor; take

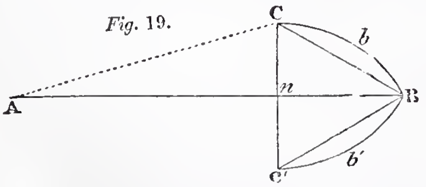
Fig. 18.



B O equal to $\frac{3}{8}$ of A B, according to the recognised proportions of anchors, and about O describe the arc C B C′, making B C and B C′ each equal to 60°. Draw B C, B C′, C C′; then B C, B C′ are the direct lengths of the arms, and C C′ is their span which divides B O equally in n. As C B n is a right-angled triangle, we have $C n^2 = BC^2 - Bn^2$, or $Cn = \sqrt{BC^2 - Bn^2}$, and $CC' = 2\sqrt{BC^2 - Bn^2}$; but $Bn^2 = \frac{1}{4}BC^2$, hence $CC' = 2\sqrt{\frac{3}{4}BC^2} = BC\sqrt{3} = BC \times 1{\cdot}732$.

Again, let A B, fig. 19, be the shank of the improved anchor,

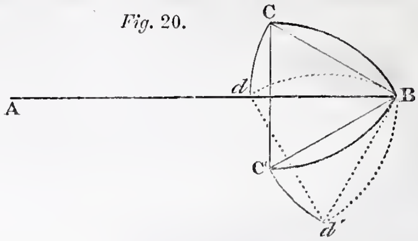
Fig. 19.



being made equal to A B, fig. 18. Make B n equal to C n, fig. 18, and through n, draw C C′ at right angles to A B, making n C, n C′, each $\frac{3}{10}$ of A B; then, about the centres C, C′, with the radius C C′, draw the arcs C b B, C′ b' B, and their chords C B, C′ B. These arcs will be the interior curvature of the arms, and the chords their direct lengths. B C C′ will also be an equilateral triangle, as B C and B C′ are each equal to C C′. From this it appears that the spans in the two constructions, are to each other as B C × 1·732 to B C, or as 1·732 to 1.

Now experience has determined, that at an angle of 60° with the shank is the best position for the arms of an anchor to enter the ground. Accordingly, such is the angle A B O contained by A B, B C, in figure 18. This is also the angle contained by A B, B O′ in fig. 10, when in working order, as illustrated by fig. 20.

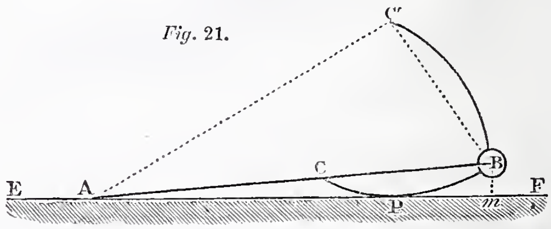
Fig. 20.



The triangle B C C′ being equilateral, its angle C B C′ is equal to 60°, and of course the angle A B C′ must be half of that, or 30°. Now, suppose the anchor to be canted and brought into the penetrating position; it then assumes the figure indicated by dotted lines, the arms turning upon their pivot at B, and describing by their extremities the curves C d, C′ d'. Here it is evident that the angle A B d' is one of 60°. Thus, while the improved anchor may have as good a hold as the common one, it has the great advantage of not presenting any upward projecting arm, as the latter does; and what is of the most importance, the circumstance of the point C coming into contact with, and resting upon the shank at d, adds greatly to the strength of the anchor, since it has the effect of shortening the leverage upon the shank, by the length of the arm, B d, at the same time that it removes the strain from the crown at B to that point.

Further, when the improved anchor comes in contact with the surface of the ground at the bottom of the sea, the parts will always arrange themselves in the position assigned to them in the drawing, fig. 21, which exhibits a mere skeleton of the an-

Fig. 21.

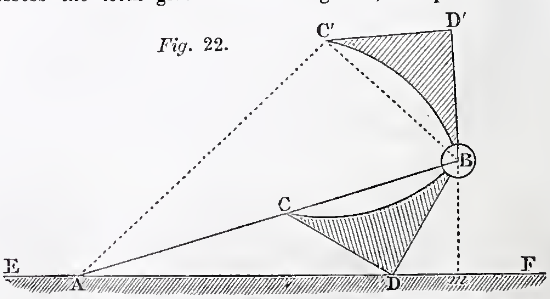


chor; the lower arm B C will rest upon the ground at the point P, the extreme point C will be pressed up against the shank A B by the weight of the latter, which of course operates forcibly by reason of the free motion of the joint at B.

Here it is evident, that no anchorage can be secured, unless the extremity of the arm is brought to bear upon the ground. For this purpose, the simple expedient has been adopted of appending a stub (technically termed a *horn* or *toggle*) upon the back of the arms, just at the point P, where it rests on the ground. It is plain then, that in this case, when the anchor is dragged along by the strain A E of the cable, the toggle becomes a fulcrum through which the crown B is raised, and the point C consequently lowered into contact with the ground.

Instead of the horn or toggle alluded to, suppose the arms to possess the form given them in fig. 22; the position there

Fig. 22.



assigned to the anchor is analogous to that exhibited in fig. 21, and also to that of the anchor in fig. 11, and it is quite plain that the point D fulfils the office of a fulcrum in turning up the lower arm B D C, when the anchor is drawn at A.

In applying the testing machine to the improved anchor, the bolt in the crown becomes, in reference to the shank, the fulcrum upon which one end of the shank rests; the point of the upper arm, upon the shank at the trend, indicates the place of the load, and the purchase of the shackle, the power. In relation to the arms, the bolt clearly becomes the point of the load; the extremity of the upper arm the place of the power; and the body of the under arm the fulcrum. Thus, the shank and the arms both operate as levers of the second kind. And here lies the gist of the matter. Turning to fig. 10 which exhibits the construction of the common anchor, the shank A B may strictly be considered as in itself fulfilling the office of a bent lever of the second kind. For when force is applied obliquely at A, the strain is concentrated upon the cross section at B, and tends to cause a fracture laterally; the leverage of the power being A B, the upper edge of the section constituting the fulcrum, and the resistance consisting of the cohesion of the particles throughout the depth of the section. The remarks apply also to any other section at the crown liable to the strain.

Now, if we conceive the fulcrum removed from the upper edge of the section at B, to that of the trend at O, it is evident that the leverage upon the cross section at that point would be reduced from the distance A B, to the distance A O. By so much, therefore, would the tendency of the shank to the rupture be diminished. This is precisely the state of the case with the patent anchor. The fulcrum is removed from the crown to the trend of the shank, at the tip of the upper arm; and, moreover, the strain at the crown, instead of encountering an imperfect welding, is transmitted to the transverse bolt, which may be proportioned with any degree of strength. In the second place, it is to be remarked, that while, in the common anchor, the strength of the under arm alone is brought into activity, that of both the arms in the patent anchor is exerted at once. but the mere fact of this being the case, does not bestow any superiority upon the anchor. We notice this, because we observe that much has been said about the advantageous diffusion of the strain throughout all the parts of the anchor—words in a great measure without meaning—for it is obvious that the lateral stiain, which in the case of the common anchor tends to rupture the lower arm at the crown, is just equal to that which, in the improved anchor, tends to separate the arms from each other at the same place; the only distinction being, that whereas in tho latter case, the strain upon the arms is distinct from that upon the shank—in the former case these lateral strains become really identical. There yet remains, nevertheless, the important advantage in the improved anchor, that the arms may be forged of one continuous piece of iron from end to end, while, in the common anchor, a welding at the crown is necessary. In accordance with what has been said, it may be remarked, that in the former anchor, the middle points of application of force in both levers (the trend of the shank and the crown of the arms, namely,) are made the stronger parts.

The shank of the patent anchor is shorter by one-tenth, and the arms longer by one-sixth, than the same parts of the common anchor. The relief of the shank from the cross strain is therefore augmented in that proportion.

In conclusion, we notice some of the results of experiment with the patent anchor, from which it will be found that the superiority claimed for the anchor is fully borne out.

Fig. 23.

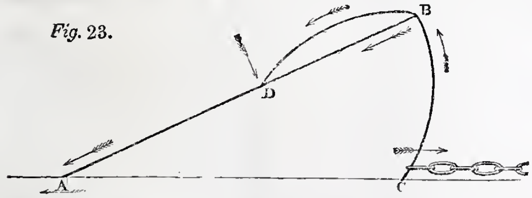
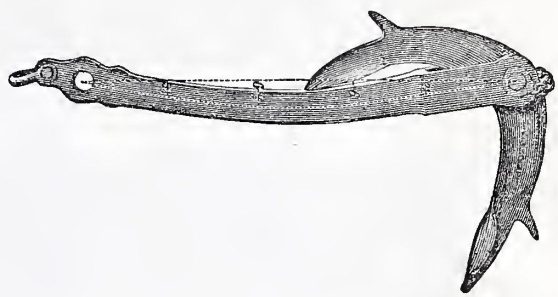


Fig. 23 illustrates the method of testing. The shackle at A being firmly secured, a chain is attached to the end of the fluke at C. The power of a hydraulic press is brought to bear upon the anchor by the medium of this chain, and the opposing forces originating at the points A, C, as indicated by the arrows, affect the whole system in the manner represented. It is obvious that the anchor is tested in the severest manner, the force at c being applied to the extremity of the fluke. Such an extreme case must be unfrequent in practice, as it will occur only on rocky or otherwise impenetrable ground.

An anchor of 1092 lbs. weight, or $9\frac{3}{4}$ cwt., was brought to the testing machine. The proof strain for this anchor, according to the government standard, is $11\frac{25}{32}$ tons; at a pressure of not less than 36 tons, a fracture appeared in the under side of the shank at a short distance within the extremity of the upper arm. Here the pressure was $\frac{21}{32}$ above the triplicate standard proof for an anchor of $9\frac{3}{4}$ cwt. With tbe strain increased to 42 tons, it broke short in the upper arm, the iron appearing perfectly sound and of good quality. This experiment proves how correctly the parts of the anchor were proportioned.

An anchor of 28 cwt. deflected $\frac{1}{8}$th of an inch under a pressure of 20 tons, but this was within the limits of elasticity; at $27\frac{1}{8}$ tons' pressure, the testing strain, it sustained no perceptible difference of deflection. The pressure was increased to $60\frac{1}{2}$ tons, the strain test for an anchor of 84 cwt. This anchor had been found unsound in the workmanship, in one of the arms, and for that reason it had been rejected for service; yet with this unsoundness, which had been discovered before the anchor was placed in the testing machine, it bore treble the pressure of an anchor of 28 cwt., the strain test for which is only $27\frac{1}{8}$ tons, and then it gave way in the lower arm which had been found defective, as shown in

Fig. 24.



An anchor weighing $5\frac{1}{2}$ cwt., of which the standard proof strain was $8\frac{5}{8}$ tons, actually sustained additional strains until it reached $20\frac{1}{2}$ tons before it gave way, nearly $2\frac{1}{2}$ times greater than would ever be required under ordinary circumstances.

At Dunston Iron Works, a patent anchor weighing 5 cwt. 2 quarters, 4 lbs., was tested, and on the power being applied, it resisted the enormous strain of 27 tons, when the upper arm gave way at about 15 inches from the crown, the under arm still remaining firm. It was then suggested, with a view to try the effect of a further strain, *without the action of the upper pea on the shank* (the upper arm being broken), when the same anchor parted in the shank at about a third from the crown, with only 16 tons strain, giving conclusive evidence of the strength imparted by its peculiar construction, when the leverage is shortened by the upper pea resting on the shank. The jaws, bolt, &c., have never been injured or strained in the slightest on this or any other occasion.

Sufficient variety is to be found in the experiments above detailed, and it would be needless to multiply examples. The following experiment on one of Perring's anchors contrast favourably with the preceding; the anchor weighed 96 cwt., 3 quarters, 5 lbs., suitable for a first rate ship of war; a strain of 60 tons was progressively brought upon it, when the point of the fluke was drawn forward $2\frac{3}{4}$ inches, from its first position. When the pressure increased to $66\frac{3}{4}$ tons, the fiuke had yielded $4\frac{1}{2}$ inches; and the moment the strain was 68 tons, or two tons above the proof, the shank broke completely through, at about 18 inches from the crown.

An anchor on Porters' construction of this weight, would sustain 120 tons pressure, without injury to the system.

In conclusion, we find that each member of the system is not only capable of resisting the strains, to which it is constantly subjected, far above the standard test which experience has long sanctioned; but, from numerous and unqualified testimonials from experienced seamen who have employed the patent anchor, we have evidence of its capabilities also in withstanding those severe shocks to which anchors are ever exposed. In the combination

of the materials forming the patent anchor, we see the power brought into action always proportioned to the respective strain. Objections might be taken at first sight to a fancied insecurity of the hinge joint, particularly of the cheeks of the shank which receive the arms, and of the bolt which connects them; yet, as we have already stated, to resist progressive force, or to withstand sudden shocks, those parts of the system have never given way. It may therefore be safely inferred, that the cheeks and bolts, as they are in practice proportioned for different classes of ships, are abundantly steady and secure with the arms and shanks to which they are related, against all accidental shocks upon the ground, and to resist strains treble those required to be withstood by the standard measure. This will be proved, no doubt, by the Government trials of strength about to take place.

BOWSER'S MODE OF CASTING SQUARE-THREADED SCREWS.

Fig 1.

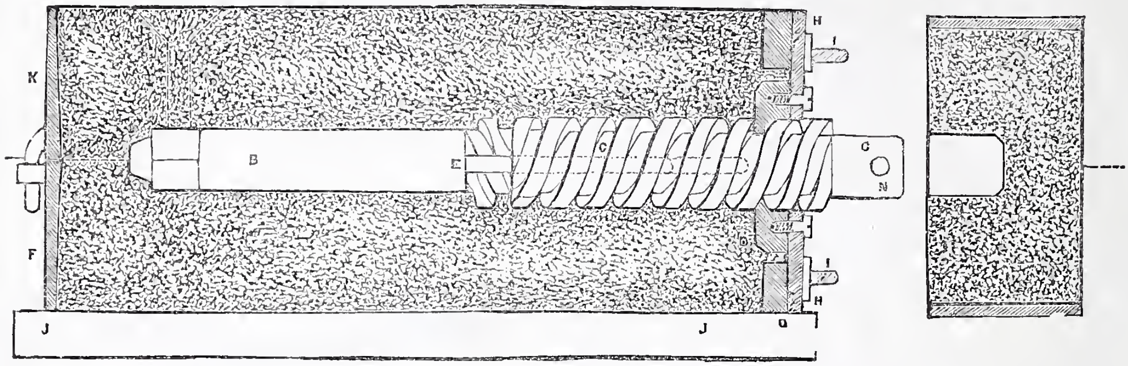
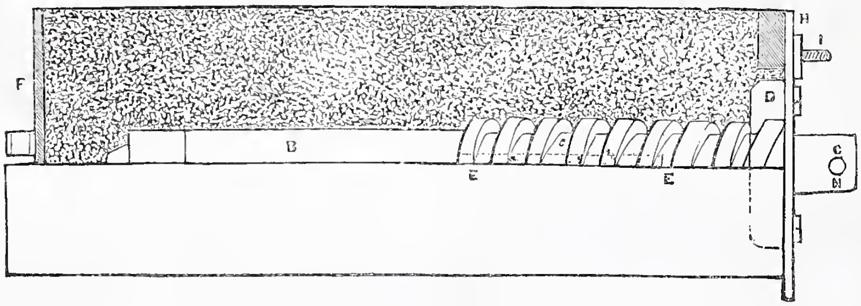


Fig 2.



The difficulty of casting square-threaded screws by the ordinary method, is owing to the nature of the spiral curve of the thread, which, presenting its angle of inclination parallel with the axis in opposite directions on each side thereof, prevents the possibility of removing the pattern without displacing some of the sand. To remedy this defect, Mr W. Bowser has contrived a plan, by which the patterns of square-threaded screws may be withdrawn from the sand and still leave perfect impressions for casting.

Instead of using only two flasks in casting any particular pattern, Mr Bowser forms the mould for the screw in three flasks, two of which contain the upper and lower halves of the mould for the body of the screw, and the third one that for the mould of the head.

A metal plate, of size sufficient to cover the end of the two long flasks when placed together, is attached to them, and has in its centre a screw-nut, which holds the pattern screw in its right position in the sand, at the division of the two halves, to form the required mould.

When the pattern of the body of the screw is to be removed from the sand, a key is introduced into the end of the pattern which passes through the nut, by turning which key the pattern is screwed out of the mould; the nut, which is firmly secured to the plate, affording the necessary resistance.

The plate and nut are then removed, and the third flask, containing that portion of the mould in which the head of the screw is to be cast, is joined to the two long flasks, when the whole is ready for casting.

Figs. 1 and 2 exhibit sections of the flasks and screw in the different stages of the process.

A A, (fig. 2,) is a board prepared to receive half of the pattern screw, by having a hollow formed in it, so that the remaining half projects above the top of the board; B, C C, and D, are the three portions of the pattern.

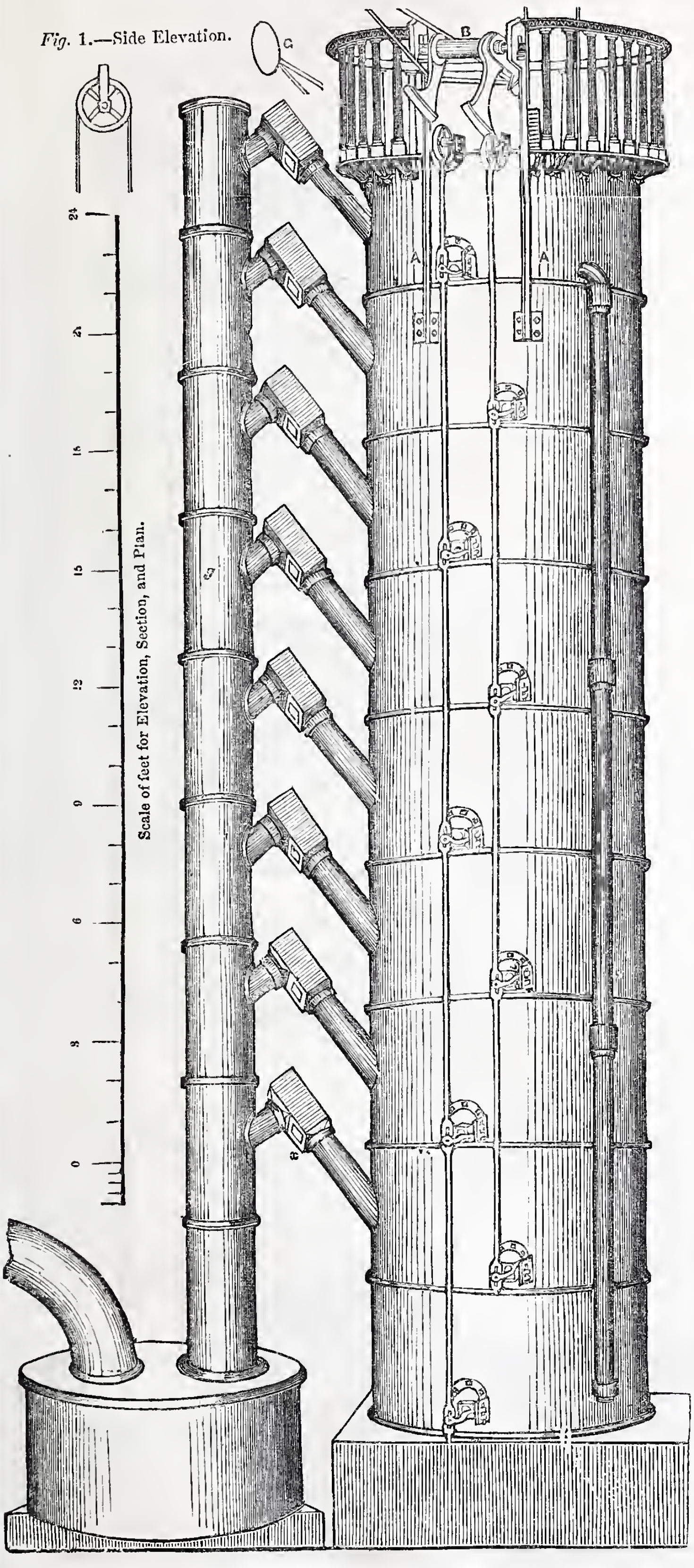
The portion B is furnished with a pin E E, which passes into a cylindrical hole in the screw portion C, and serves to guide the pattern when being screwed out of the sand.

The part D has a hole properly cut to allow of a passage for the pattern to be removed. F G is part of one of the long flasks shown in section, and placed on the board A A. In the end G is a semi-circular aperture, sufficiently large to allow of the sand being pressed in round the collar D. A metal plate, H H, is then screwed to the pattern collar D, and to the flask F G by two screws I, I. Sand is next filled into the flask and rammed solid to the top, as shown by the dotted sloping lines.

A second board J J (fig. 1,) is now fixed to the top of the flask F G, and the whole being turned over, the board J J becomes the lowest. The first board, A A, is then removed, which leaves half the pattern above the sand. The first half of the mould is then made good if any defects are found in it; and the flask K L is then placed over and secured to the flask F and also to the plate H H. Sand is then filled into the top of this flask, and rammed solid as before, which completes the impression of the body of the screw. The plate H is next removed in order to attach to the two long flasks, by means of the screws I, I, the end flask M M, which is filled with sand to take the impression of the head. This done, the end flask M M is removed, and the plate H H is again secured to the flasks F G and K L, and also to the collar D.

The screw portion of the pattern is now withdrawn, and in order to remove the plain portion, the upper and lower flasks are separated, and then all the flasks being once more united, a proper opening is made in the sand, and the metal poured in to obtain the cast.

Fig. 1.—Side Elevation.



DESCRIPTION OF THE BLOWING MACHINE AT THE IRON WORKS OF VECKERHAGAN, WESTPHALIA.

By M. De Marignac, Mining Engineer.

This machine was constructed as far back as 1832, at the works of M. Henschel, of Cassel, to whom I am indebted for the following drawings.

At the iron-works of Veckerhagen, it is of importance to economise as much as possible the motive power, which consists of a fall of water of $26\frac{1}{2}$ feet in height, but which in dry seasons does not afford more than 40 cubic feet of water per minute.

General Description.—The machine is composed of eight cylindrical cast-iron compartments, divided from each other by horizontal plates, *a*, (fig. 2,) of cast-iron—the compartments communicating with one another by openings *b* in the bottom plates, to which the valves *h* are adapted. The arrangement is such that the compartments 1, 3, 5, 7, simultaneously discharge the water which they contain into those immediately below them, marked 2, 4, 6, 8; at the same time that this discharge takes place, the air contained in these last is displaced by the water and forced through the pipe *g* into a general reservoir. The movement being reversed, the compartments last filled, discharge their water into those immediately below them.

The body of the machine, then, consists of a cylindrical column divided into eight compartments, which communicate with one another by the openings *b*, and with the main pipe *g* through the tubes *f*, which are fitted into smaller openings *c* in the bottom-plates of the compartments. The first openings allow the water to pass from one series of compartments to a lower series; and the smaller openings allow the air to escape under the water-pressure, resulting from the descent of the water into the air chest through the main pipe *g*. The passages *b* for the escape of the water are formed of short-pipes which project downwards, sufficiently far that the water in the compartments with which they communicate shall always be above the level of their lower ends.

The valves *h* of these escape passages *b* are connected by wrought-iron levers *s*, which pass through the side of the cylinder, and are fixed to cast-iron forked pieces *k*, which turn in bearings *l l*, and are at the same time attached by moveable connexions to the vertical rods *n*. These connexions are shown on a large scale by figs. 11, 12, 13, in page 240.

The openings in the metal of the main cylinder, through which the valve levers pass, are made water-tight by coverings of strong leather. To form this joint, the levers are screwed at that part to receive two large nuts. One of these nuts is first passed upon the arm as far as required; then the leather, by a hole cut in it large enough to allow it to pass upon the arm up to the nut; the second nut is then screwed tightly up against the first, so that the leather is retained firmly between them.

Each of the air tubes *f* is connected to the main pipe *g* by a valve-box *o*, represented on a larger scale by figs. 8, 9, 10. In this box are the two valves *x* and *y*; that marked *x* is to allow the air from the atmosphere to pass into the corresponding compartment, when discharging its water into that below it; and the other *y* is to prevent the air from returning from the reservoir into the cylinder. These valves, therefore, work alternately. When a cylinder is discharging its water into

that below it, the atmospheric valve x is open and the valve y shut; and when the cylinder is being filled with water, the atmospheric valve x is shut and the other y is open, allowing the air, previously admitted by the valve x, to pass into the reservoir.

Above the eight blowing cylinders is placed a distributing cylinder, A, (fig. 1.) The bottom of this cylinder is in part formed by the cover of a rectangular box, P, which rises to such a height, that a float s in the cylinder No. 1, can rise into it half its thickness. Besides the discharge pipe and its valve, the distributing cylinder is provided with a small cylinder H (shown in figs. 2 and 4), which communicates by the pipe R, with a chest T—see figs. 2, 3, and 4. The piston of the cylinder H, (which is open to the atmosphere), is connected to an arc which is fast upon the axis V. Upon this axis are two arms w, which act upon the ends of the rods n, causing them to ascend and descend alternately—the arms being so arranged, that as the one rod rises, the other is depressed. To render the action of the arms more easy, friction-pulleys Z are placed upon the ends of the rods to receive the oblique action of the arms.

The rods n, urged upwards by the weight of the valves, tend always to maintain their highest position, so that the weight of the valves and the motion of the water suffice to raise and shut the valves; but to depress the rods, a very considerable force is required. For this reason the rods terminate in friction pulleys upon which the inclined planes terminating the arms w, are made to act. It will also be observed that the extremities of the arms w, have contrary inclinations, so that when one rod is being depressed, the other is suffered to rise.

The valve levers k are connected alternately with the rods n, so that in the working of the machine, the alternate valves will be elevated, whilst the others are depressed, and reciprocally.

The axes of the sectors, w, turn in cast-iron bearings, formed on brackets made fast to the side of the upper cylinder. Again, the same axis, V, carries a balance B, with a counterweight G, which effects the depression of one of the rods n; to complete the action, the piston in the cylinder H depresses the other rod n, and at the same time raises the counter-weight O.

The chest T has two openings in the bottom provided with valves: the one O opens downwards, and communicates with the distributing cylinder A, which is full of water, and in which the chest T is placed; the other valve L opens upwards, and shuts the communication between the water-pipe E, which descends to the bottom of the machine, and enters below the surface of the water in the lowest compartment. (See fig. 1.) The rods P P of these valves pass through stuffing-boxes upon the cover of the chest T, and are connected at O′ and L′ to the horizontal axis, F, in such a way that whenever this axis turns 90° in either direction, the two rods are both raised or both depressed at the same time, thereby causing the one valve to open and the other to shut. (See fig. 4.)

Upon the prolonged end of the axis, F, is put a loose pulley, G; round this a cord passes, of which one end is attached to the float, s, and the other passes over a pulley, Y, and carries a counterweight, which is intended to balance the excess of weight of the float.

Fig. 2.—Vertical Section.

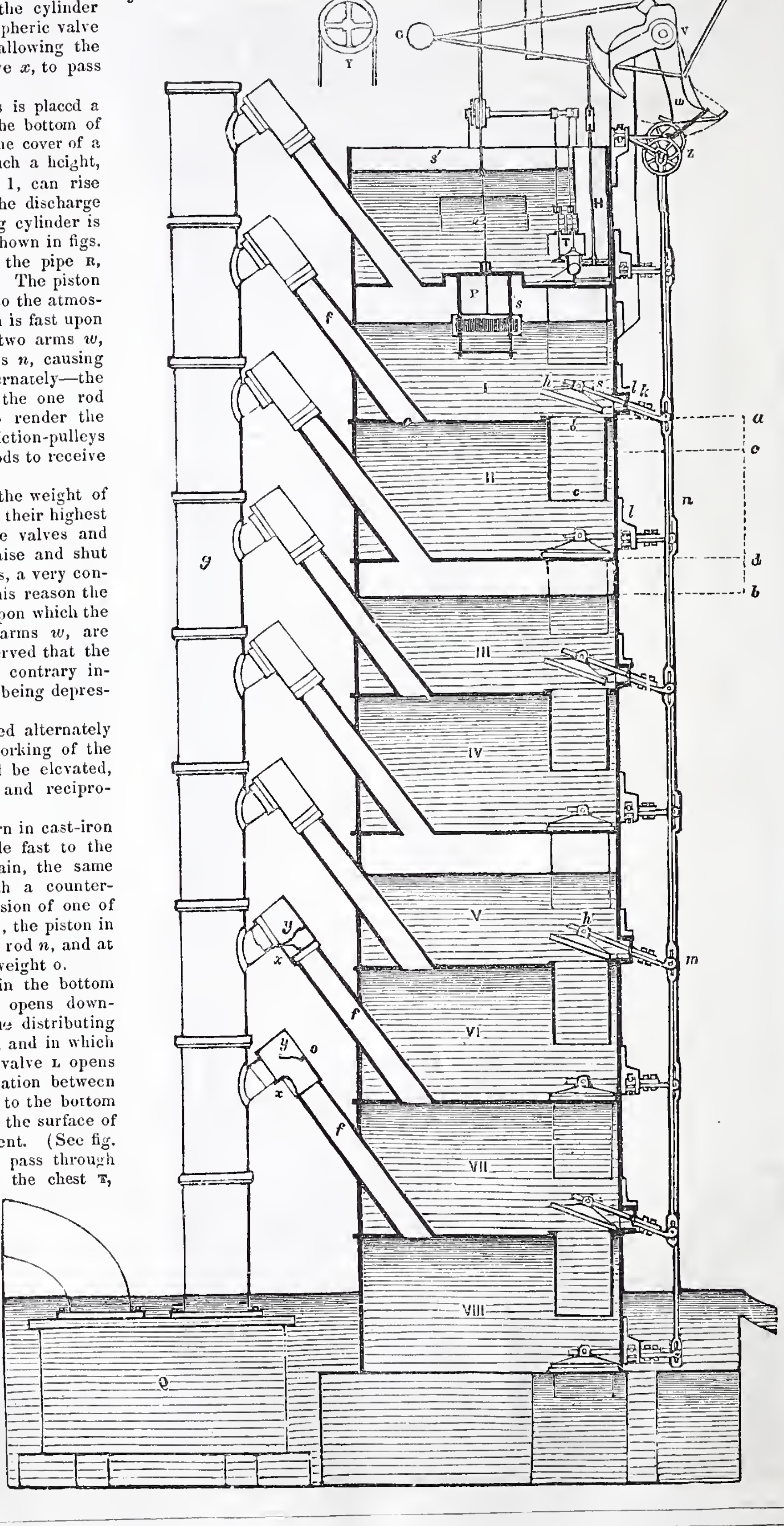


Fig. 4.—Distributing apparatus.

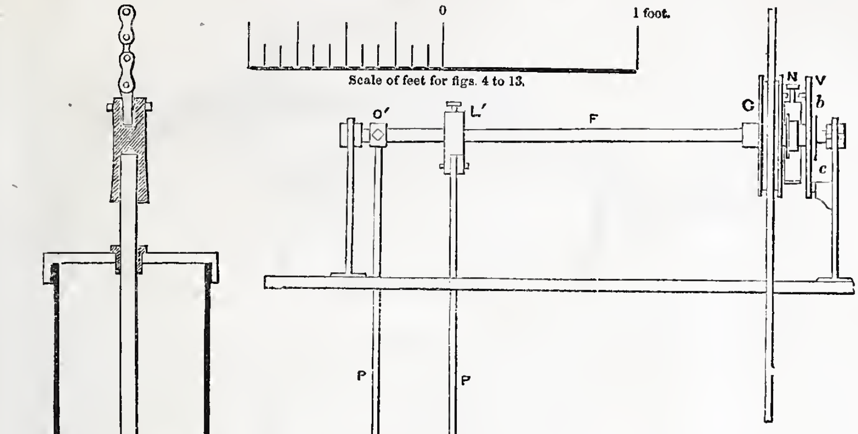
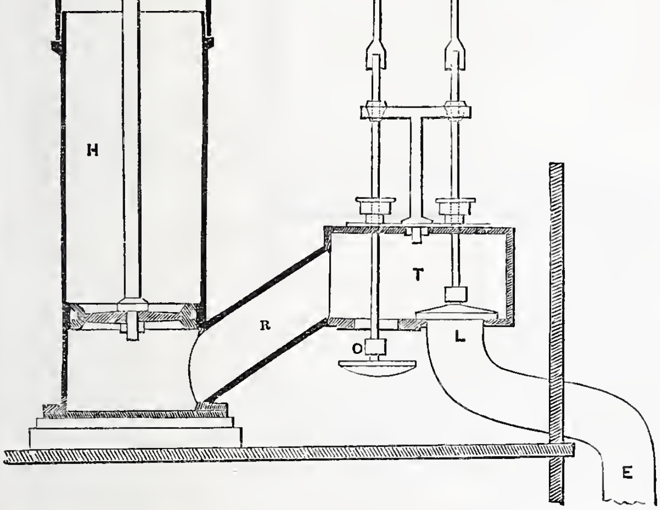



Fig. 5.

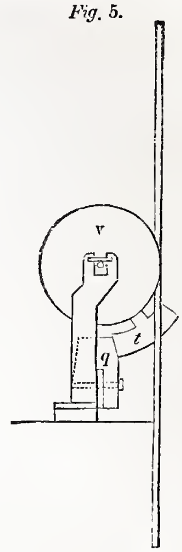


Fig. 6.

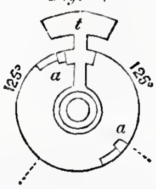


Fig. 7.

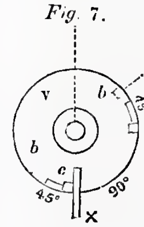


Fig. 8.

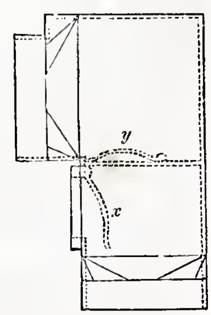


Fig. 3.—Plan of the Machine.
(Same scale as Figs. 1 and 2.)

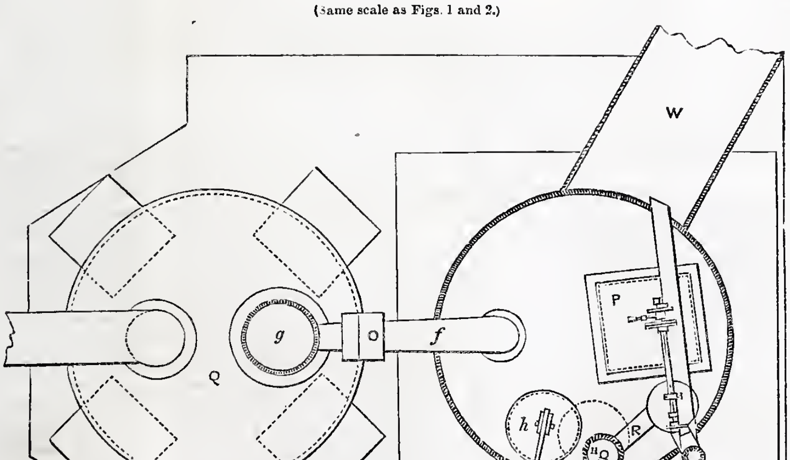


Fig. 9.

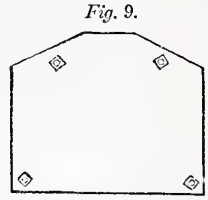
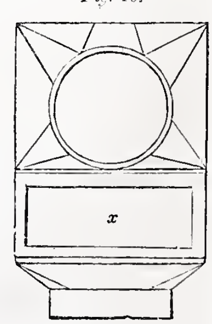
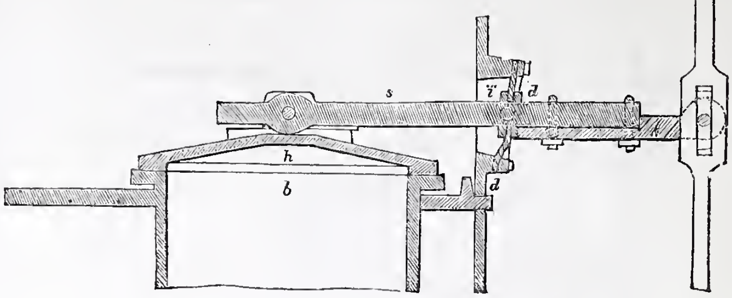


Fig. 10.



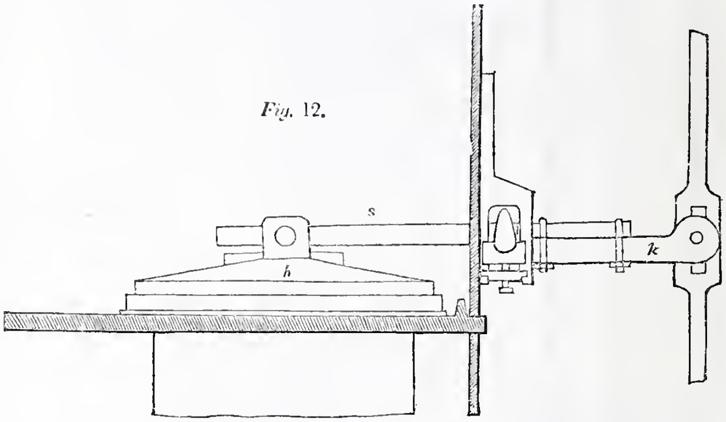
The float, *s*, in ascending and descending, gives motion to the loose pulley G. On tho side of this last, is placed a weighted tumbler *t*, which turns equally freely upon the common axis F, and is raised by the pulley O, by means of the two stops *a a* fixed upon the pulley, as shown in fig. 6. Whenever the tumbler attains the vertical position, as in fig. 6, it falls over by its own weight upon the other side, upon the stop *b* (fig. 7), fixed to the side of the pulley V, which is fast upon the axis F, and which being thus made to turn, the requisite change of disposition of the valves O and L is effected. The stops are so fixed, that the fall of the tumbler causes the crank O′ and L′ to turn through an arc of 90°, first in one direction, then in the opposite.

Fig. 11.



The air thrown in by the two series of cylindrical compartments, is conducted by the main pipe *g*, into the air-chest Q, placed under water, and thence to the furnace. For the purpose of regulating the velocity of the blast, a valve is placed in the supply-pipe a little before the tweres.

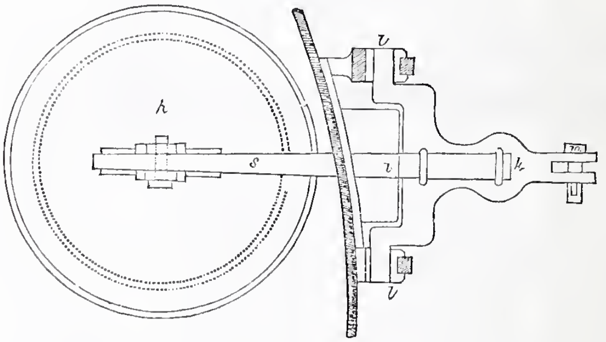
Fig. 12.



The water is conducted into the distributing cylinder A, by the canal pipe W, (fig. 3), through the opening *o*′, (fig. 2), and fills the cylinder to the height *s*′.

If it be desired, at any time, to fill or empty the cylinders completely, the blast should be more prolonged, and the changes of direction less frequent; but the pressure would, at the same time, vary considerably. While the machine is in action, it will, however, be better that the water should not fall in the cylinders more than a foot above the bottom, and thereby preserve always a height sufficiently great in the cylinders to avoid tumultuous motion in the water at the instant in which it descends from one cylinder to the other.

Fig. 13.



This precaution is especially necessary for the regular action of the float. For the same reason, the water, at its greatest height, remains one foot below the bottom, in order that the air may always have free egress; and to avoid the inconvenience which would result from small differences in the construction and refilling of the cylinders.

From the arrangement described, it is clear that the pressure of the blast at its maximum and minimum, is measured by the columns of water *a b*, and *c d*, (fig. 2); that is, the maximum variation of the pressure of the blast is equal to double the height to which each cylinder is filled.

In the position represented in the drawing, fig. 2, the first series of compartments, 1, 3, 5, 7, have discharged their water into the second series, and have expelled their air into the main pipe *g*; at the same time they have admitted a charge of atmospheric air by the valves *x*. The distributing cylinder A is filled with water to the level *s*′, and is ready to discharge it into the cylinder No. 1. At the instant the float attains the lowest point of its travel, the pulley G, with which it is connected, has raised the tumbler *t* to the vertical position; and this descending on the other side, strikes upon the snug fixed to the pulley V, fast upon the axis F, thereby causing it to turn through an arc of 90°. By this operation the rods P P are depressed, and the one valve closes the opening L, and the other opens that marked O. At that instant, the piston of the cylinder, H, being freed from the pressure of the column of water which fills the tube E, the weights G cause the reversing balance to turn on its axis, and raise the piston of the cylinder H, which is filled with water by the opening O of the chest T, and acts upon the levers *m*, which, by means of the rods *n*, open the valves *h* of the cylinders 2, 4, 6, 8, and shut those of the second series, 1, 3, 5, 7. The float then ascending gradually turns the loose pulley G, and raises with it the tumbler *t*, which again attains the vertical position at the instant the float arrives at the highest point of its travel; but the tumbler falls again upon the second snug of the fixed pulley V, which it causes to turn 90° backwards, so as to bring the whole back to the original position. The rods P P rising, the valve O shuts, and L opens; the column of water contained in the tube E then acts with its whole weight upon the piston of the cylinder H, which descends; the weight O is raised, and the levers *w*, leaving the rod *n* of the second series, open the valves of that series to allow the water to escape into the cylinders of the first series.

The water expended runs from the last cylinder into a basin from which it escapes by a notch; to facilitate the escape, the water in the basin is maintained at a level lower by three feet than the lowest water-line of the last cylinder. If the level of the water were too high in this basin, the water of the last cylinder would not have time to empty itself completely; consequently, when the outer basin would empty its water into it, it would rise more and more, and ultimately ascend into the blast-pipe.

Experience has shown, that the surface of the water in the basin may be allowed to fall, advantageously, to six inches below the lowest level that it can attain in this cylinder.

The little irregularities which may occur in the refilling of

the cylinders, regulate themselves by the action of the machine, provided that the lowest cylinder may always empty itself to the convenient level.

If, in consequence of a want of water, the distributing cylinder is not filled completely with water, before the instant in which it ought to empty its water into the cylinder No. 1, this one would be filled more slowly than the other; the float would also ascend more slowly, and the consequence would be, that the valves not opening in time, the coupled cylinders would empty the water too soon into the inferior cylinders, which would thereby be filled before the proper time. Besides, the cylinder H would run dry, and the air finding access under the piston, would injure the working of the machine.

Thus the necessary conditions for the proper action of the machine are, first, that the distributing cylinder does not refill too slowly; secondly, that the lowest cylinder does not discharge its water too slowly.

Of the principal Dimensions of the Machine.—In blast furnaces wrought by wood charcoal, the pressure of the blast varies generally between 28 and 40 inches of water. We may take the amount of discharge of the cylinders at 11 inches of their depth; the variations of pressure which result from this are very trifling, on account of the reservoir acting as a regulator. It is easy now to calculate the number of cylinders which may be employed. From the height of the total fall H, there must be subtracted,

1° To guard against variations of the superior level, and to accelerate the refilling of the distributing cylinder, ...	0·669 ft.
2° The difference between the level of the water in the lower basin, and the lowest level which it ought to reach in the last cylinder, ...	0·238
3° The height of the stratum of air contained in the last cylinder at highest water level, . . .	0·866
Total,	1·773

There remains then the height H—1 foot 9¼ inches, which must be divided into an even number of parts, in order to have a mean pressure between 28 to 40 inches; we will thus have the number and height of the blowing cylinders. In the establishment where this machine is in operation, the total fall of water is 26½ feet. There remains then, 24·687 feet, which is divided among eight cylinders of a mean height of 3·086 ft. The greatest variations of pressure are comprised between 2·22 and 3·952. If we allow a tenth for the resistance due to the motion of the water through the escape pipes, there remains

1·997	for the minimum pressure of the blast.
2·778	. . mean . . . .
3·557	. . maximum . . . . . .

It is of importance never to estimate too largely the depth of discharge in the cylinders; it ought never to exceed 14·165 inches, even for blast furnaces wrought with coke, which require a strong pressure of 4¾ to 5⅓ feet of water.

The section of the cylinders depends upon the quantity of air which may be required. Admitting that a blast furnace wrought with wood-charcoal, seldom requires more than 1200 cubic feet of air per minute at atmospheric pressure; if the machine make 10 strokes per minute, and four cylinders be worked each stroke, the effective volume of each cylinder will be $\frac{1200}{10 \times 4} = 30$ c. ft., and the cross section will be $\frac{30}{\cdot866} = 34\cdot64$ sq. ft., that is 36·08 sq. ft., adding 1·443 sq. ft. for the section of the escape pipes, which diminishes the area exposed to the air. The diameter of the cylinder will then be 6·33 ft., and the quantity of water expended 5×30 or $\frac{1200}{8} = 150$ cubic feet per minute.

Section of the Escape Pipes.—This is regulated by the quantity of water which is delivered per minute, which in the present instance is 150 cubic feet. But regard must be had to the resistance opposed to the motion of the water by the valves; and also to that which results from the changes of direction of the motion of the machine, the escape being interrupted 10 to 12 times a-minute, during intervals of about two-thirds of a second. In practice also the section of the tubes has commonly been taken considerably greater than that given by calculation: the sectional area in the present case is 1·42 sq. ft., and the diameter 1·34 ft. The thickness of the tubes is ¼ inch, so that their exterior section is 1·44 ft. Each of the escape pipes, through which the water flows from one series of compartments to that below, must descend below the lowest level to which the water falls in the cylinder into which it escapes.

Of the Air Pipes.—These tubes ought to allow 1200 c. ft. of air, at the pressure of the atmosphere, to flow through them per minute; or

$$1200 \, \frac{33}{33 + 2\frac{1}{2}} = \frac{39600}{35\cdot5} = 1114$$ c. ft. of air at the mean pressure of 2½ feet of water above atmospheric pressure.

The main-pipe g has a cross sectional area of ·6759 ft., and the tubes which conduct the air to it from the cylinders have each a cross sectional area of $\frac{\cdot6759}{4} = \cdot1689$ sq. ft. or a diameter of 4·92 inches.

Reversing Gecr.—Let n be the greatest number of valves in operation at once; f^2 the section of each valve; $a\,c$ the maximum pressure acting upon them; 62·5 lbs. the weight of a cubic foot of water; the force necessary to depress one of the rods connected with the levers of the valves will be

$$L = n f^2 \times a\,c \times 62\cdot5.$$

Following the arrangement of the levers which act upon these rods, and the connexion of the piston-rod to their axis, the force transmitted by the piston H is increased in the ratio of 1 to 10. If we augment the force by one-third for sundry resistances, and still double it on account of the raising of the counter-weight O, we will have for the force which ought to move the piston,

$$K = 2 \times \frac{4}{3} \times \frac{L}{10}$$

Here $n = 5, f^2 = 1\cdot296$; $a\,c = 3\cdot952$; then $L = 1600$ lbs., and $K = 426\frac{2}{3}$ lbs.; which represents 6·82 c. ft. Take 9½ cubic ft. which makes sufficient allowance. The height of the column of water being 26½ ft., we will have ·3214 sq. ft. for the area of the piston of the cylinder, and ·567 ft. for its diameter: The stroke of this piston is 1·42 ft., it rises five times per minute; it therefore expends 1·746 c. ft. of water per minute.

The section of the column of water is determined by the condition that the water contained in the cylinder H runs off in two-thirds of a second, the time fixed for the change of direction in the distribution. Let h be the stroke of the piston (1·42 ft.); K, its section $= \cdot3214$ sq. ft.; $v =$ the velocity with which the water flows in the escape pipe, n the section of this tube; we will have $n = \frac{h\,k}{\frac{2}{3}\,v}$; the height from which the water falls in the escape pipe will be $\frac{h\,k}{n}$: then the velocity which it will receive, would be $v = \sqrt{2\,g.\frac{h\,k}{n}}$; but this velocity will be considerably diminished by inertia and hydraulic resistance. We ought therefore to abstract ⅓d of this velocity, and to take

$$v = \frac{2}{3}\sqrt{2\,g\,\frac{h\,k}{n}}$$; consequently

$$n = \frac{h\,k}{\frac{4}{9}\sqrt{2\,g\,\frac{h\,k}{n}}} \text{ or } 16\,n^2 = \frac{8\,h^2\,k^2}{2\,g\,\frac{h\,k}{n}} \text{ and } n = \frac{81\,h\,k}{32\,g} = \cdot04017$$

cubic feet.

This tube has a sectional area of ·047 sq. ft., or a diameter of ·2174 ft.

The pulley connected with the rod of the float is 0·595 ft. diameter.

The float is a square piece of sandstone, of 1·559 foot on the side, and ·567 foot in thickness; its content is therefore 1·455 cubic foot. It is sustained by the counter-weight P, so that it

only sinks half its depth into the water, in consequence of which the force which it can exercise is equal to the weight of half its volume of water, that is to

$$\frac{1{\cdot}455 \times 62{\cdot}6}{2} = 45{\cdot}4187 \text{ lbs.}$$

Each of the snugs $a\ a$ fixed to the loose pulley, raise the tumbler 135° to its vertical position; they are then at an angular distance of 270°.

The fixed pulley on the axis q, carries four snugs; two interior ones $b\ b$ at the extremities of one axis destined to receive the shock of the tumbler, and two exterior ones $c\ c$, situated 90° apart, and at 45° from each of the snugs $b\ b$. They are intended to strike against a fixed piece x, when the pulley has turned 90°. At the same time, the tumbler is stopped by a fixed piece, to modify the effect of its shock upon the moving parts of the machine.

Useful effect of the machine.—It is easy to calculate the useful theoretical effect of this machine. The moving force is the product of the quantity of water (q) expended by the height of the fall H; the effect produced is the product of the quantity of air thrown in (w) at the atmospheric pressure by the height of water (h) corresponding to the pressure at which it is injected; then the useful effect $x = \frac{w\,h}{q\,\text{H}}$; now theoretically, the volume of air injected, being equal to the volume of water expended, multiplied by the number a, of blowing cylinders, $w = a\,q$; then, $x = \frac{a\,h}{\text{H}}$. Here, $a = 8$; h is the mean pressure of the air $= \frac{3{\cdot}557 + 1{\cdot}997}{2} = 2{\cdot}777$, and $\text{H} = 26\frac{1}{2}$ ft.; then $x = 0{\cdot}84$, supposing that the air is ejected at the same pressure at which the machine delivers it, and that the regulating valve (*registre*) placed in the air-pipe is entirely open.

The useful real effect of this machine is given by the following experiments, to understand which, it must be remembered that:—

1°.	The total height of the fall of water is .	$26\frac{1}{2}$ feet.
2°.	The section of each blowing cylinder is .	25·23 sq. ft.
3°.	The depth of discharge in each cylinder .	·866 feet.
4°.	Capacity of the air space in each cylinder	22 c. ft.
5°.	No. of air cylinders	8

The number of discharges of the cylinders has been measured in these experiments, by counting the number of falls of the tumbler of the distributing apparatus per minute.

The gage was placed upon the extremity of the air-pipe, before the leather neck which connects the pipe with the jet-piece (*buse*); the tube has there 10·4 inches diameter; the distance of this point to the orifice of the jet-piece is 11·34 feet.

In the experiments No. 1, 6, 11, the regulator valve in the air-pipe was entirely open.

No. of the Experiments.	No. of discharges of the first cylinder per m.	Water consumed per minute in cubic feet.	Height of the gage in feet.		Section of the orifice of the jet-piece in sq. ft.	Quantity of air delivered in cubic feet.	Leakage of air.		Useful effect.
			Water.	Mercury.			cubic ft. per min.	p. cent.	
1	3·00	65·8		1·7	2·63	468·4	58·04	11·0	0·61
2	2·83	62·0	2·1			449·8	46·74	9·4	0·57
3	2·75	60·3	2·0			434·1	48·51	10·0	0·53
4	2·58	56·3	1·6			388·5	64·20	14·1	0·41
5	2·50	54·8	1·5			376·6	62·10	14·1	0·39
6	2·50	54·8		1·7	2·20	392·0	46·74	10·6	0·62
7	2·41	52·8	2·1			376·5	46·32	10·9	0·56
8	2·25	49·4	2·0			363·2	73·81	8·0	0·55
9	2·25	49·4	1·6			325·7	69·85	17·6	0·40
10	2·12	46·5	1·5			315·1	56·77	15·2	0·39
11	2·00	43·9		1·8	1·79	327·7	23·20	6·6	0·68
12	1·58	34·6	1·4			311·4	29·86	10·7	0·38

These experiments show that when the regulator is open, for a mean pressure of 2·29 to 2·42 feet, this machine has an effect of more than 60 per cent; that when the quantity of water in motion, and the orifice of the jet are diminished, that effect rises to nearly 70 per cent.

Expense of Construction of the Machine:—

		£	s.	d.
1°.	For patterns of various pieces, . .	£11	6	$7\frac{1}{2}$
2°.	Expense of moulding and casting, .	18	17	9
3°.	Do. of fitting, forging, &c., . .	32	18	$5\frac{1}{2}$
4°.	Do. of construction of the various parts of the distributing apparatus, and of the brass-work and material, ...	62	4	$0\frac{1}{2}$
5°.	Erection of the machine, lead for the joints, &c., ...	18	6	$9\frac{3}{4}$
6°.	Sundry expenses, ...	6	17	$3\frac{3}{4}$
	Total,	£150	11	0

In round numbers, the machine required in its construction $23\frac{1}{2}$ tons of cast-iron, and 11 cwt. of forged iron.

I shall simply add, that the principle of this machine appears good; in employing the direct pressure of the water to propel the air, much friction and waste of air is avoided, but the method of reversing the motion appears to me very complicated, and I believe it could be made much more simple. In the measure of the useful effect, the water consumed has not been measured directly, but calculated from the dimensions of the cylinders; it is probable that there would be something to be added for waste of water, but it would be little. Besides, there has been no account kept of the water consumed by the distributing cylinder, which, in the preceding experiments, must have amounted to 1 or 2 cubic feet per minute. But in regard to that, it would not diminish the useful effect more than 2 per cent.

BOOTH'S PATENT MODE OF CONVERTING RECTILINEAR INTO ROTATORY MOTION, AND THE CONVERSE.

The essential action of Mr Booth's mode of conversion of motion, is resolvable into the well known mathematical principle, that if a straight line of fixed length is in motion, and its ends move in two straight lines that are at right angles to each other, the centre of the straight line will describe a circle of which the diameter is equal to that line. Let A B, fig. 1, be the straight line, and C D, E F, be two other straight

Fig. 2.

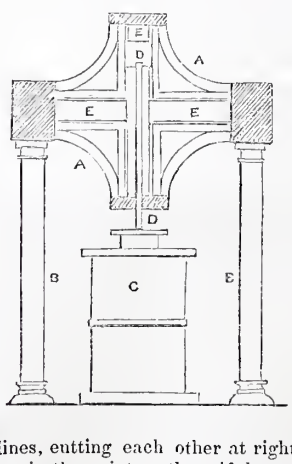
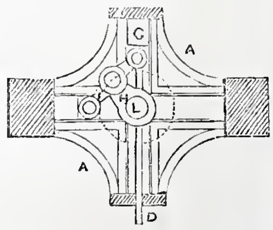


Fig. 3.



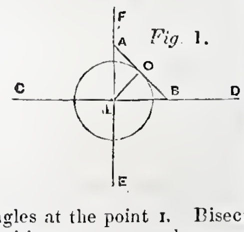


Fig. 1.

lines, cutting each other at right angles at the point I. Bisect A B in the point O; then, if the extremities A, B, move and remove alternately along the respective lines E F, C D, on both sides of the point I, the point O will continually describe a circle upon the centre I, having the diameter I O.

Fig. 2 is a sectional elevation of this principle as applied to a steam-engine. Fig. 3 is a detached view of the frame-work A A, showing the arrangement of the parts of the motion. The pillars B B support this frame-work. C is the steam-cylinder, D the piston-rod, fixed to a cross head perpendicular to the plane of the drawing attached to the slide D, which moves in the vertical

groove, E. S is the crank-shaft, H the crank, and I a rigid connection, represented by the line, A B, fig. 1, of which the extremities are attached respectively to the slides, D, in the grooves, E E, vertical and horizontal, and the middle point working on the pin of the crank, H. It is obvious, that motion being imparted by the piston-rod, the extreme centres of the link, I, will be moved through the slides along their respectives grooves, and that their compound motion will move the crank-pin in a circular path, causing the main shaft to revolve.

HUNT'S PATENT GOLD-WASHING MACHINE.

With the late discoveries of vast auriferous deposits, which have suddenly opened up a new industrial field, and given so immense an impulse to emigration, a natural demand has arisen for improved machinery, by which the severe manual labour of the gold-digger may be lessened, as well as his profits augmented. The apparatus hitherto commonly employed for this purpose has been of the simplest description, and it cannot be doubted, that while so much has been gathered, a vast amount of the precious metal—sufficient to enrich a nation—has been wasted and lost in the meantime. The metal, indeed, is indestructible; and future gleaners may collect, by the aid of improved apparatus, enough of the glittering treasure to enrich them, even from the very refuse of those who have already traversed the field.

Several improved machines have been devised for treating the ore in different manners, according to the state in which it is found in the soil, or imbedded in minute fragments in the solid rock. One of the best of these, in point of simplicity of construction, as well as in efficiency of operation, is Mr. Hunt's apparatus for separating small particles of gold from auriferous ores, by the mere process of washing. The patent for this machine is dated July 16, 1852. Mr. Hunt, the patentee, has been for many years concessionaire and director of the ancient mine of Port Peau, near Rennes, in France, and has, therefore, had much official experience in the proper treatment of ores with a view to their separation from foreign matters. His machine is adapted for the treatment of auriferous ores in that state in which they are most extensivly found, the gold being generally diffused in exceedingly minute grains, which, by a careless system of washing, are swept away, to a large extent, with the refuse.

The details of this machine, which are exceedingly simple, will be very easily understood by reference to the annexed cuts. Fig. 1 is a perspective view of it, complete; D being the ore-receiver, which is shown detached in fig. 3, and C a square force-pump, shown, likewise detached, in fig. 2. The water is introducted at B. The ore-receiver, D, is furnished with a copper bottom, which is either finely pierced or woven. Fig. 4 is a tray, F, for receiving the very fine particles of gold which pass through this copper sieve. Fig. 5 is a scraper for removing the refuse; G is the force-pump handle, for putting the machine in motion; I, the handle of the screw which raises and lowers the ore-receiver, D; J is a tube which carries back the water from the top of the ore-receiver to the part, B, when water is scarce; and K (fig. 3) is the spout by which the water escapes when not required to be used a second time.

The operation of the machine will now be easily understood from the mere details of its construction. It ought to be placed perfectly level, and, of course, in the most convenient situation for obtaining an adequate supply of water; although, at the same time, when water is scarce, it furnishes the means of economizing it to the best advantage. The auriferous or other mineral matter to be washed, must first be passed through a common sieve, the holes of which should be one-third of an inch square. If any gold is found, by careful examination,

Fig. 1.

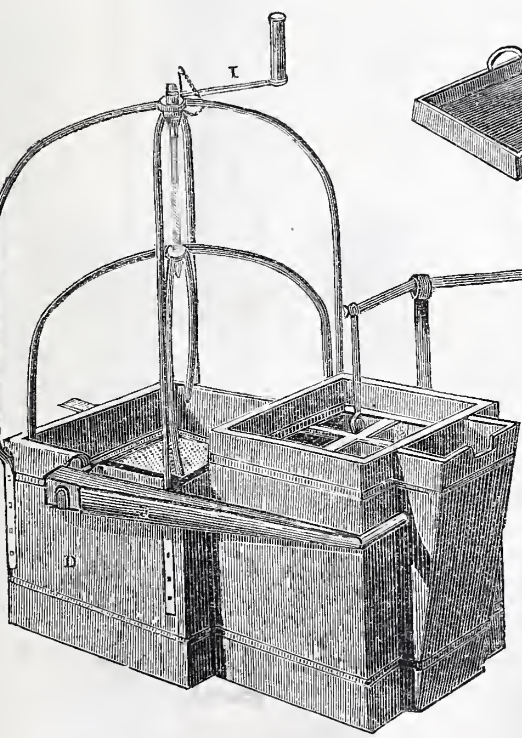


Fig. 4.

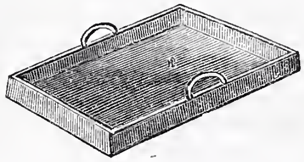
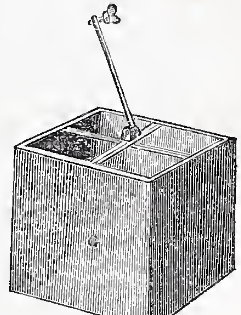


Fig. 2.



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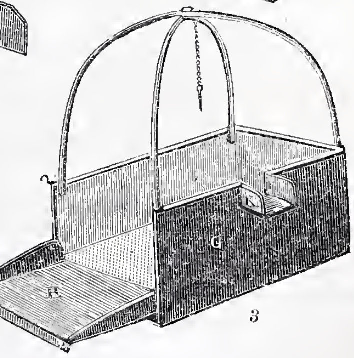


3

among that which remains on the sieve, it can easily be picked out, the fragments being sufficiently large. The matter that has passed through is then put into the receiver, D, until within one inch and a quarter of the bottom of the water-escape, K or J, taking care that it is placed as level as possible on the woven or perforated copper bottom of the box. Water is then introduced at B, and the force-pump, C, which has likewise been filled with water, in order to counterbalance the lift, is put into rapid motion by means of the handle, G; the perpendicular stroke to be about one inch and a quarter.

The action of the pump causes the whole of the matter in the ore-receiver, D, to be set in motion; and the consequence is, that the gold or other minerals, according to their specific gravity, quickly subside to the bottom. The very minute grains of gold, which are sufficiently small to pass through the copper bottom of the ore-receiver, D, will descend into the tray, F, below; the larger grains will remain on the copper bottom, as on a fine sieve. The gold, as it thus accumulates on the bottom of the ore-receiver and the tray, may be removed when desired; but will require to be again washed to clear it from some sand which will still be mixed with it, and this may be done at the end of the day's work, or when it is considered that a sufficient quantity has been accumulated. It is proper to examine pretty frequently the tray, F, under the receiver, and to have it emptied when full.

The force-pump is kept in motion about one minute and a half for each charge; the gold will then be precipitated. The next operation is to raise the ore-receiver by means of the screw-handle, I, as far as a hole drilled in the under part of the screw, when a small iron pin is introduced, as shown in fig. 1, to keep the ore-receiver in its place until the refuse is removed. For this purpose the falling-door, H, in the side is opened, and the refuse is removed with the scraper, fig. 5. To avoid removing any of the gold which has not been perfectly thrown down, care must be taken to leave about half or three-quarters of an inch of the mineral matter at the bottom. The door, H, is then shut up, and the receiver is screwed down to its place, in which it is kept fast by a pin of iron, introduced into a hole behind the handle.

When water is plentiful, and not required to be used over again, the tube, J, is removed, and the hole where the small end enters, is, in that case, shut by a slide fixed inside B, for this purpose. When water is scarce, the same supply may be used a great many times by means of the tube, J, until it become so much charged with muddy matter as not to be any longer fit for use, in which case it must be poured off, and a fresh supply procured.

The patentee states, as the result of repeated trials, that, after passing the auriferous sand through the preliminary ordeal of the sieve of three square holes to the inch, one active man can wash, with a full-sized machine, about six hundred pounds an hour of this auriferous material. Supposing, therefore, that each hundredweight produced only twenty grains of gold—a very low estimate indeed—the net result would be equal to about two ounces a day, of eight hours' working.

SELF-ACTING APPARATUS FOR BORING BY PERCUSSION.

APPLICABLE TO THE SINKING OF SHAFTS AND BORING FOR MINES OR QUARRIES.

By M. Cavé, Engineer, Paris.

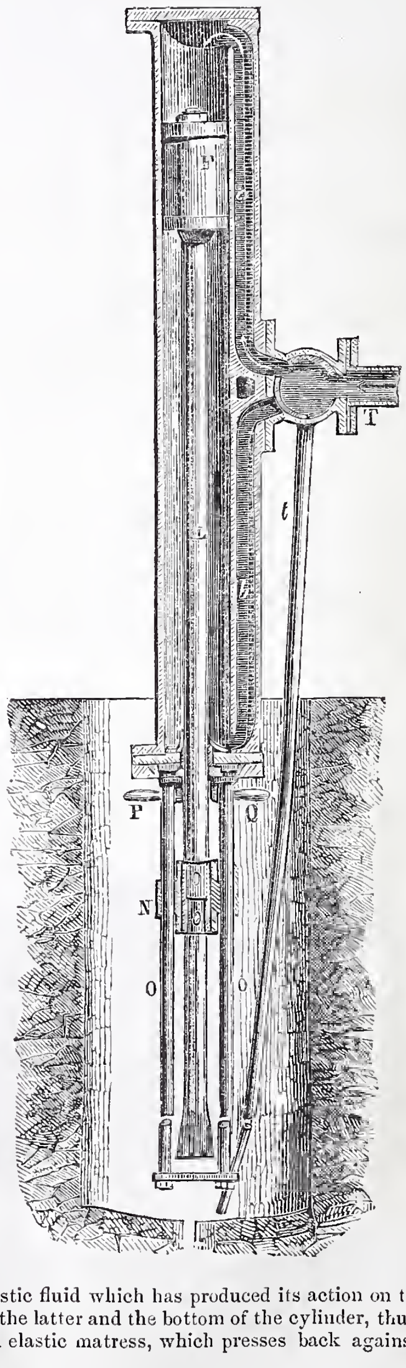
(*Patented in France 15th October*, 1851.)

M. Cavé, whose mechanical reputation is European, has recently devised a very ingenious apparatus, which is calculated to be of the greatest service in replacing the fatiguing manual labour of quarriers, miners, and excavators in general. This machine, which may be put in motion either by compressed air, or by steam or gases, or even by a vacuum, is intended to perform the most difficult and laborious work in the operation of piercing for wells or excavating subterranean galleries, working stone-quarries, coal-pits, and all other mining operations.

The structure of the machine is distinguished by the greatest simplicity; in fact, it simply consists of a cylinder, which may be always reduced to the dimensions of the openings intended to be made, and enclosing a piston, the elongated rod of which carries a piercer, chisel, or graver—any instrument, in short, proper for boring, or for penetrating into the hardest rock, acting by percussion, like successive strokes of a hammer.

It will readily be perceived, that the great difficulty in forming an apparatus to operate in this manner by percussion, was to construct the mechanism so that the different parts, being all reduced to the most rigorous dimensions, might, for a long time, resist the wear and tear of incessant action, notwithstanding the shocks to which they are exposed from the sharp and repeated blows of the instrument against a rocky material. M. Cavé succeeded in resolving these difficulties by a most simple and ingenious arrangement, which perfectly accomplishes the end in view. For this purpose, instead of permitting the escape of the air or gases by the same passages through which they are introduced, he has placed near the latter other lateral tubes, which do not terminate, like the first, at the extremities of the cylinder, but at some distance from these extremities, so as to leave a portion of the air or

Fig. 1.

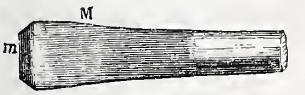


other elastic fluid which has produced its action on the piston, between the latter and the bottom of the cylinder, thus forming a natural elastic matress, which presses back against the pis-

ton when it reaches the end of its course, and so prevents it from striking against the bottom of the cylinder.

This new and peculiar arrangement will easily be understood from the following description, with the aid of the annexed cuts:—

Fig. 1 represents a longitudinal section of this machine, along the axis of the cylinder, and the orifices for introducing the steam. From this figure it will be seen that the mechanism consists of a cylinder, J, in which works the piston, K, of any ordinary construction. The rod, L, of the piston is prolonged a considerable length beyond the end of the cylinder to receive the chisel or cutting-tool, M, which varies in form and size according to the kind of work to be done. The socket, N, by which the piston-rod is connected with the cutting instrument, serves for a guide to the former by sliding on the two parallel rods, O, which are used when the piston has a long range to accomplish, but may be dispensed with in numerous cases. The annexed cuts show the form of the chisel, and its cutting edges, *m*, for piercing the rock.



The handles, P, which are firmly connected with the disc or plate, Q, supporting the two rods, and which is adjusted on the cap of the cylinder, afford the means of turning the piston-rod and chisel as often as required, in order that, by changing its direction, the sharp edge of the chisel may constantly strike different points of the rock or stone on which it is brought to bear.

Fig. 2 is a second longitudinal section of the apparatus by the axis of the cylinder, and the middle of the escape-pipes, to a scale of one-fifteenth the proper size.

Fig. 2.

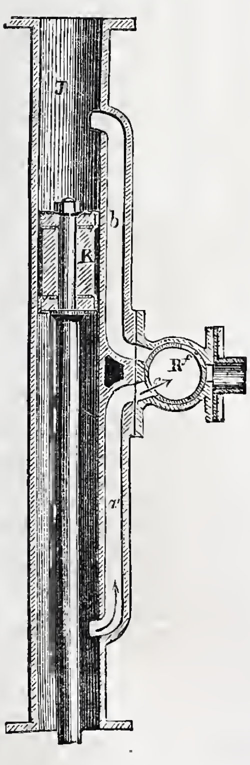
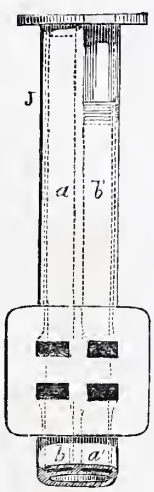


Fig. 3.



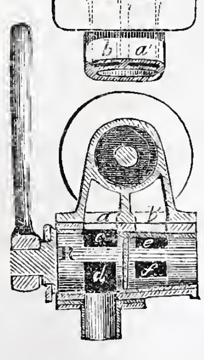


Fig. 4.

Fig. 3 is a representation, on the same scale, of the exterior of the apparatus in front, with the orifices for the introduction and escape of the elastic fluid.

Lastly, fig. 4 is a horizontal section, by the axis, of the distributing apparatus.

OPERATION OF THE MACHINE.

It will at once be perceived, that if air, or any compressed gas, be introduced by the pipe, *a*, over the piston, K, this air or gas, by its elastic force, will cause the piston to descend rapidly to the other end of the cylinder, and by the momentum acquired, it would strike like a hammer on the bottom of the cylinder, if it were not kept back, on arriving at the end of its course, by the elastic matress already mentioned.

It will be seen that the escape-pipe, *a'*, which is opposed to the entrance-pipe, *a*, (fig. 1,) opens at a certain distance from the bottom of the cylinder, so that when the piston has nearly reached this extremity, it encounters the resistance of the yielding portion of air or gas which remains in this space, and which, being compressed against the lid of the cylinder, forms a natural spring, which deadens the stroke of the piston.

On the other hand, the same effect is produced by the retrograde movement; the compressed air or steam rushes into the lower part of the cylinder by the pipe, *b*, and drives the piston upward; when near the top, it is again checked or deadened by the bed of compressed steam or air which remains in the space between that extremity of the cylinder and the mouth of the escape-pipe, *b'* (fig 2).

This arrangement of the escape-pipes, so as to be independent of and quite distinct from the admitting-pipes, resolves the most difficult and delicate problem which was to be encountered in those kinds of operations in which percussion is applied, inasmuch as it fulfils this essential condition—namely, "the deadening of the strokes of the piston at each end of its course,"—and enables the operations to be carried on with the greatest safety, without danger of breaking any parts of the mechanism, however severe the repeated strokes of the chisel or other tool employed. As it is quite new, M. Cavé has reserved for himself its exclusive application in France to every kind of machine or apparatus in which percussion is employed, and for all operations to which it admits of being applied.

To form the distributing apparatus, the inventor applies on the cylinder a kind of spigot with several openings, R, enclosed in a box, which is fixed to the cylinder. By turning this cock the one way or the other, its orifice, *d*, (fig. 4,) is made to communicate with the admission-pipe, T, which communicates with the reservoir of the gas or steam, and its orifice, *c*, either with the pipe, *a* or *b*. In the former case, its third opening, *e*, is in communication with the escape-pipe, *a'*, (fig. 2,) and in the latter it is, on the contrary, its fourth orifice, *f*, which is in communication with the pipe, *b'*.

At the discharge of the stop-cock, a tube, *t*, is applied, which is carried to the chisel or other working-tool, to convey to the surface operated upon the air or gas which has produced its effect, and thus to clear the hole, as it is pierced, of the rubbish or debris which would impede the action of the instrument.

This apparatus may be made so light as to admit of being carried by the miner, and placed in the position which he judges most suitable, to pierce or dig into the rock either in a horizontal, or vertical, or oblique direction; thus, the subjoined cut (fig. 5) shows the application of the apparatus when intended to excavate a gallery in hard rocks. He may always manage with one hand the distributing cock or spigot, which permits the air or gases to work the piston, and with the other direct the course of the cutting instrument.

In other cases, the machine may be mounted on a moveable sledge or car, or on any other kind of stand or support.

It is obvious, also, that the apparatus may be so constructed as to admit of the piston-rod being armed with several piercers or cutting instruments instead of one; or that it may even be composed of several cylinders, on each of the piston-rods of which several chisels may be mounted. In all cases, each of the cutting-tools may be attached, either on the prolongation of the piston-rods, or eccentrically in connection with them, so as to permit of operation on a surface more or less extended.

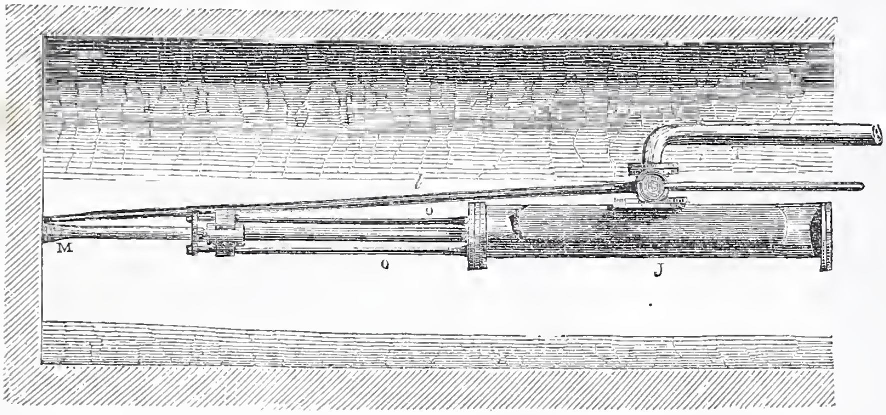
Thus, to pierce a well, the apparatus might be combined in

such a manner as to carry a centre or pivot, round which might be placed several cylinders, working a series of tools, in order to excavate at once all the circumference and central part of the hole. A similar arrangement would evidently serve for piercing any kind of gallery. Or one might construct, as the inventor has done, a car or truck carrying a bundle of cylinders, which might be directed according to the form of section intended to be given to the excavation.

M. Cavé proposes to apply this process in boring artesian wells, by employing a hollow probe or piercing-shaft, at the end of which would be placed the cylinder—its piston to be moved by an interior mechanism, which would be always in communication with the workman outside the well.

As the pipe, T, which conveys the air or gases to the cylinder, may be prolonged at pleasure to any required extent, in proportion as the latter is removed from the source of the moving power, it is easy to see that the distribution may always be under the control of the workman, whatever be the depth or distance at which the apparatus is required to operate.

Fig. 5.



It is needless to observe that the compressed air for working the machine, must be produced by a fixed prime-mover, acting by condensing syringes, placed in any suitable position outside the mine or quarry, and that it may always be conveyed to the bottom of the latter, whatever be the direction of the well or other excavation to be made, because the conducting-pipe, T, of metal, caoutchouc, or gutta percha, may always be prolonged and branched off in any direction.

The apparatus may be equally made to work by means of a vacuum; and in many cases this may be attended with great advantage, because the vacuum would permit the abstraction of the gases which are attended with so much danger in coal-pits, especially as the apparatus would be taken to those very parts of the pit where the gases are disengaged most freely.

In working also with compressed air, the injurious gases may be equally or in great measure withdrawn, being driven off by the air introduced as it escapes from the machine, because this air has a greater pressure upon it than that in the pit.

Lastly, M. Cavé thinks that this apparatus might be worked by electric currents, which, if required, would allow of its being impelled with the greatest rapidity.

To conclude, it will be seen from our description that this novel machine is calculated greatly to supersede the painful labour of miners or quarriers, and thus to facilitate, in many cases, the operations of boring and sinking, by working with much greater rapidity and economy than by any of the means heretofore employed for these purposes. And as this apparatus constitutes quite a new mechanical process, M Cavé has secured for himself the exclusive right to it in France, by a patent for fifteen years, reserving, at the same time, all the applications of which the system admits in the operations of mining and manufacturing industry, and of adding to it, according to circumstances, such modifications as may be deemed necessary.

PHOTOGRAPHY, OR PHOTOGENIC DRAWING, THE CALOTYPE, DAGUERREOTYPE, &c.

CHAPTER IV.

THE CALOTYPE.

In last chapter we described a variety of forms of the *camera obscura* used for photographic purposes; we quoted Sir David Brewster's recent important discovery connected with that subject, and concluded by recording the welcome announcement of Mr. Talbot's resignation of his photographic patents, which may, we hope, be regarded as inaugurating a new era in the history of this delightful art. It is, therefore, with pleasure that we now proceed to explain the calotype process, which, from the name of its inventor, is sometimes known as the Talbotype.

The calotype—a term derived from two Greek words, signifying "beautiful picture or image"—was patented by Mr. Talbot in 1842. It differs from the processes already described, inasmuch as it is admirably fitted for taking pictures by the camera, in consequence of the greater sensitiveness of the preparation; while, at the same time, the paper thus prepared exhibits no visible image after exposure in the camera, till washed with a liquid containing gallic acid, which gradually developes the picture in all its details.

The process, as originally published in Mr. Talbot's specification, is still generally adopted in its leading features; but the best account of it, with some important improvements, is that which was published by Mr. Cundell in the Philosophical Magazine for May, 1844, with reference to which Mr. Hunt remarks that, "to this very clear and satisfactory description of the calotype process, is mainly due the perfection to which it has arrived, both at home and abroad;" and again, "In the main it will be found that Mr. Cundell's process of manipulation is almost as good as any that can be adopted; and that gentleman certainly merits the thanks of the patentee, and of all photographic artists." We shall, therefore, in describing the process, adopt Mr. Cundell's directions, with some very slight modifications, which have been subsequently recognized as improvements.

There are five distinct operations in producing and fixing a calotype picture, all of which, with the exception of the third, which consists in exposing the prepared paper in the camera, must be performed by the light of a lamp or candle, or in a chamber into which a subdued light is admitted through yellow glass, or through several thicknesses of yellow calico. Even the lamp or candle, when one of these is employed, should likewise be surrounded, if possible, with a yellow glass. The reason of this precaution is the passive or non-actinic influence of the yellow rays of the spectrum, as explained in our first chapter. (Vol. I. p. 542.) All the processes are very simple, but, at the same time, they must all be performed with the greatest care and attention to produce satisfactory results.

FIRST PROCESS—IODIZING THE PAPER.

The first process has been termed by Mr. Talbot *the iodizing of the paper.* We have previously given general directions for selecting the paper, and much of the success of the calotype depends on this selection. It ought to be compact and uniform in texture, smooth and transparent, and of not less than medium thickness. "The best I have met with," says Mr. Cundell, "is a fine satin post paper, made by 'R. Turner, Chafford

Mill.'" Having selected it with those precautions stated at the end of our second chapter, the object is to spread over its surface a perfectly uniform coating of iodide of silver.

This may be accomplished by either of two methods. That recommended by Mr. Cundell is nearly the same as Mr. Talbot's original specification, and consists in applying the iodide of silver by means of the mutual decomposition of nitrate of silver and iodide of potassium. In following this method, the paper is first prepared on one side with a solution of nitrate of silver, made by dissolving twenty grains in an ounce of distilled water, and applied by either of the methods mentioned in Chapter II. Every part of the surface must be thoroughly wetted; but no free or running solution must be left unabsorbed on the paper, which is then suspended by the corners, and allowed to dry in the dark. The nitrate of silver thus spread on the paper is now to be saturated with iodine, to form the iodide of silver; and this is effected by bringing it in contact with a solution of iodide of potassium, the iodine uniting with the silver, and the nitric acid with the potash.

For this purpose take a solution of iodide of potassium of the strength of one ounce to the pint of water, to which Mr. Cundell recommends, as an improvement, the addition of 100 grains of common salt. Pour the solution into a flat-bottomed dish, so large as to admit the paper, and cover the bottom with the liquid to the depth of about an eighth of an inch. Mr. Talbot directed to dip the nitrated paper into this solution, and to let it stay two or three minutes. The preferable method, however, is to hold the paper by an upturned margin, and to draw it gently along the surface of the liquid, until its nitrated face is thoroughly wetted, keeping the other side clean and dry; and, instead of allowing it to remain for two or three minutes, it should not be exposed in the iodine dish for more than a minute altogether, as the new compound just formed upon the paper would gradually be redissolved upon further exposure. The paper is, therefore, to be removed after remaining not more than a minute in contact with the iodide solution, and, after dripping, it may be placed upon any clean surface, with the wet side uppermost, until about half dry, by which time the iodide solution will have thoroughly penetrated the paper, and have found out and saturated every particle of the silver, which it is quite indispensable it should do, as the smallest portion of undecomposed nitrate of silver would become a black stain in a subsequent part of the process.

The paper is now covered with the desired coating of the iodide; but it is also saturated with nitrate of potash (or saltpetre), and with the iodide of potassium, both of which must be completely removed at this stage of the process. To effect the removal of these salts, Mr. Talbot directs to "dip the paper into a vessel of water, dry it lightly with blotting-paper, and finish drying it at a fire, or else it may be left to dry spontaneously." Mr. Cundell, however, justly remarks, that it is by no means sufficient to dip the paper in water; neither is it a good plan to wash the paper with any considerable motion, as the iodide of silver, having but little adhesion to it, is apt to be washed off. But the margin of the paper being still upturned, and the unprepared side of it kept dry, it will be found that, by setting it afloat on a dish of clean water, and allowing it to remain for five or ten minutes, drawing it gently now and then along the surface to assist in removing the soluble salts, these will separate by their own gravity, and (the iodide of silver being insoluble in water) nothing will remain upon the paper but a beautiful perfect coating of the kind required.

Mr. Thornthwaite remarks that it is a good plan, to ascertain if all the superfluous iodide has been removed, to let a drop of the liquid from the surface of the paper fall into some solution of nitrate of silver; if it produce a precipitate, the paper must be washed for some time longer; if no precipitate appears, it may now be dried. We have seen that Mr. Talbot directs to dry it lightly with blotting-paper; but Mr. Cundell states that, while wet, the prepared surface must not, on any account, be touched or disturbed with blotting-paper, or with anything else. He directs merely to suspend it in the air, and, in the absence of a better expedient, to pin it across a string by one of its corners. When dry, it may be smoothed by pressure. The paper is now iodized and ready for use, being covered with a uniform pale-yellow coating of iodide of silver.

Another method of iodizing the paper, is by means of the double iodide of silver, as proposed by Mr. Jordan. It is decidedly the most simple, and may be recommended as preferable in other respects. In the first place, dissolve about twenty grains of nitrate of silver in an ounce of distilled water, and add to this twenty grains of iodide of potassium, likewise dissolved in an ounce of water. The yellow iodide of silver is precipitated from the mixed solutions, and is allowed to settle to the bottom; the clear supernatant liquid is then drained off, and the precipitate is washed two or three times with warm distilled water, allowing it to settle down each time before decanting the liquid. By this process the iodide of silver is freed from any soluble nitrate of potass, or other impurity. Having then poured over it sufficient distilled water to make up one fluid ounce, and carefully stirred the whole with a glass rod, add to it crystals of iodide of potassium by small quantities, or even single crystals at a time, ascertaining that each crystal is dissolved before the addition of another. By degrees the solution will become clearer, and at last perfectly bright, forming what is termed *the double iodide of silver*. This solution is best applied to the paper by means of a glass rod, as described in Vol. I. p. 605; and when the surface of the paper is nearly dry, it is placed in a vessel of water, which ought to be changed five or six times in the space of nearly half an hour. It is known to be sufficiently washed when the surface of the paper becomes of a lemon-yellow colour, and when a drop of the liquid falling from it fails to produce a precipitate in nitrate of silver solution. The paper is then to be hung up, and when dry may be smoothed in the ordinary manner by pressure.

The rationale of this process is as follows:—The iodide of silver, precipitated from the solution of the nitrate by iodide of potassium, is soluble in a strong solution of the latter salt, forming the double iodide of silver. In this state of solution it admits of being applied to the paper, and the iodide of potassium is then dissolved out by the water, leaving in the substance of the paper a precipitate of pure iodide of silver.

The paper may be *iodized* by either of these methods, and in this state, says Mr. Talbot, "it is scarcely sensitive to light; but, nevertheless, it ought to be kept in a portfolio or drawer until wanted for use." He adds—"It may be kept for any length of time without spoiling, or undergoing any change, if protected from sunshine." Mr. Cundell also recommends to protect the "iodized paper" from the light; but Mr. Thornthwaite remarks, as the result of more recent experience, that "it is not in the least sensitive to light, and should bear exposure to the direct rays of the sun without the colour being affected, otherwise the process has not been properly conducted, and the exposure, far from being injurious to it, seems, on the contrary, to increase its sensitiveness." We may add, that, when it is discoloured by the light, some of the nitrate of silver must have remained mixed with the iodide.

SECOND PROCESS—PREPARING THE PAPER FOR THE CAMERA.

The second process is that of exciting, or preparing, the paper for the camera, when it is about to be used. For this purpose the paper must be washed with a liquid, which Mr. Talbot directs to be prepared in the following manner:—

Dissolve fifty grains of crystallized nitrate of silver in an ounce of distilled water; add to this solution one-sixth of its volume (or say a drachm and a half) of strong acetic acid. Let this mixture be called A.

Make a saturated solution of crystallized gallic acid in cold distilled water. The quantity dissolved is very small; about four or five grains in an ounce of water. Call this solution B.

Mix together the liquids A and B in equal volumes, but only a small quantity of them at a time, because the mixture does not keep long without spoiling. About three drops of each will be sufficient, added to two drachms of distilled water. This mixture Mr. Talbot calls the *gallo-nitrate of silver*. As it speedily changes, it must be used without delay, and should not be prepared until the operator is quite ready to apply it.

The application of the "gallo-nitrate" is made in the following manner:—It is poured upon a clean and level slab of plate-

glass, on the surface of which it is diffused to a size corresponding to that of the paper. The paper being then held by a narrow upturned margin, its prepared side is applied to the liquid upon the slab, and is brought in contact with it by passing the fingers gently over the back of the paper, so as to exclude any air-bubbles, taking care that the back is not soiled by the solution. As soon as the iodized paper is properly wetted with the gallo-nitrate, it is to be removed from the slab into a dish of pure water, in which the excess of the gallo-nitrate is carefully washed off; or this may be done by a sheet of fine white blotting-paper, free from water-mark, laid over its surface, and very lightly pressed. Five or ten seconds, at the most, is as long as it is safe to leave the paper to be acted upon by the gallo-nitrate. When surface-dry, it may either be placed, while still damp, in the camera frame between the plate-glasses ready for use, by which it is protected as much as possible from the action of the atmosphere; or it may be kept in a portfolio, among blotting-paper, for some time. If properly prepared, it will keep perfectly well for four-and-twenty hours at least, preserving all its whiteness and sensibility.

Paper thus prepared is exquisitely sensitive to light, an exposure of less than a second to diffused daylight being quite sufficient to set up the process of change. If, however, the paper is required of its utmost degree of sensitiveness, as for portraits, the quantity of water employed to dilute the gallo-nitrate may be greatly reduced, even to a few drops; in which case the whole process must be quickly and skilfully performed, as it rapidly decomposes, and will not keep longer than two or three minutes. The proportions above stated afford the best average strength; but the proper degree of dilution is a point to be acquired by experience, and must be proportioned to the brightness of the day, or brilliancy of the object.

THIRD PROCESS—THE EXPOSURE IN THE CAMERA.

On this subject Mr. Cundell remarks that, "as the operator must be guided by his own judgment, few directions can be given, and few are required. He must choose or design his own subject; he must determine upon the aperture to be used, and judge of the time required, which will vary from a few seconds to three or four minutes. The subject ought, if possible, to have a strong and decided effect; but extreme lights, or light-coloured bodies, in masses, are, by all means, to be avoided."

When the paper is taken from the camera, the impression is latent and invisible. It is true, that if the paper be placed aside in the dark, it will gradually *develop itself;* but when removed from the camera, very little, or, more commonly, no trace whatever of a picture is visible until it is subjected to the

FOURTH PROCESS—BRINGING OUT OF THE PICTURE.

The solutions required for bringing out the latent picture are the same as those employed for preparing the paper, viz., solution of gallic acid and aceto-nitrate of silver. About half a drachm of each of these solutions may be added to half a drachm of distilled water; and this mixture is applied to the paper in the same manner as before, taking care that the surface is thoroughly wetted all over. The paper is then laid, with the impressed side upwards, on a plate of glass or other clean substance, and the picture will gradually appear in all its details. The most perfect pictures are those which "come out" before any part of the paper becomes dry, which they will do if sufficiently impressed in the camera, and if the manipulations have been otherwise well managed. In any case the surface must be kept wet during the development of the picture, otherwise the lights sink and become opaque; and this is done by applying, when necessary, a fresh mixture of the gallo-nitrate. In cold weather, the picture will generally be tardy in making its appearance; and in that case the process can be much accelerated, and a better result obtained, by the cautious application of heat. If exposed, however, in the dry state to heat, the paper will embrown. It is, therefore, recommended to hold the picture over the vapour from some hot water placed in a rather deep dish, or to expose it to a horizontal jet of steam. If any part of the picture begin to stain, although wet with the gallo-nitrate, the whole of the excess of the latter should be briskly removed from the paper by a glass rod drawn across it horizontally, and a quantity of the solution of gallic acid alone should then be poured upon the picture. This will generally allow of its development, without being deformed by stains or dark waves.

FIFTH PROCESS—FIXING THE PICTURE.

The fifth and final process in procuring the negative image, is that of rendering it permanent; and this is accomplished by removing from the paper the sensitive matter, which consists of the excess of nitrate of silver, and also of the yellow iodide. For this purpose, when the picture is sufficiently developed, it ought to be immediately washed, by placing it, face downwards, in a vessel of clean water, and moving it gently to and fro, without allowing it to settle at the bottom of the vessel. The water should be changed three or four times in a period of less than ten minutes. The photograph is then to be removed, and pressed between some folds of clean white blotting-paper, which, as for all photographic purposes, ought to be entirely free from lines and water-marks. Some use warm water for washing the picture, but not warmer than may be borne by the finger. The washing removes the greater portion of the gallo-nitrate; and any remaining trace of this salt, together with the iodide of silver, is to be dissolved out, after draining with the blotting-paper, by placing the picture in a warm and strong solution of hyposulphite of soda, which may be made by dissolving about four ounces of that salt in a pint of water. This solution is poured into a flat dish, and the photograph is soaked in it for two or three minutes, turning it and moving it occasionally, and taking care not to withdraw it till the yellow colour of the iodide disappears. The paper is then washed in common water to remove the hyposulphite of silver, and any remaining unreduced salts; and this washing is repeated two or three times, to insure their complete removal; or, if time can be allowed, the paper should be left to soak in a fresh quantity of water for several hours. It is then dried between folds of blotting-paper, when the picture will be found perfectly fixed, and may now be exposed to the light without undergoing any change.

The minuteness with which we have described these five several processes—all of which must be performed to procure a *negative* calotype—may render them apparently tedious; but they are really by no means difficult; and after a little practice in the manipulations, may be performed with ease and almost certain success. If the chemical agents employed be perfectly pure, and the *intention* of each separate process kept in view, the operator, following these minute directions, may calculate with confidence on the result.

THE PRINTING OR TRANSFERRING PROCESS.

The proper work of the calotype is now performed—a beautiful photograph on paper is procured; but this photograph is still only a *negative* -the lights and shades, as well as the positions of the objects, are all the exact reverse of nature. But it has been justly remarked, that "if it have cost some trouble to produce this *negative* picture, that trouble ought not to be grudged, considering that you are now possessed of a matrix which is capable of yielding a vast number of beautiful impressions. I have had as many as fifty printed from one, and I have no doubt that as many more might be obtained from it."

There are various methods of obtaining *positives* from *negatives*, for which the reader is referred to the details in Chapter II. Any of the processes described in that chapter may be adopted for printing or transferring the negative photograph. The paper prepared with ammoniacal nitrate of silver, having been previously washed in a solution either of muriate of barytes or common salt—a process minutely described at p. 604, Vol. I.—is generally preferred for the purpose.

The negative photograph is likewise prepared for yielding a good impression, by lightly burnishing the surface on which the picture is impressed. This is done by laying the photograph on a smooth glass plate, and applying a steel or agate burnisher to various parts of its surface, till the whole is equally smoothed and polished, so as to transmit the rays of

WROUGHT-IRON BAR-CHAIN SUSPENSION BRIDGE, ERECTED [illegible] COMMAND OF THE EMPEROR [illegible]

FROM MODEL DESIGNED BY [illegible] TRAFALGAR SQUARE, AND EXHIBITED CLASS VII Nº 10[illegible] GR[illegible]

light more perfectly. If the light parts of the negative are not sufficiently transparent to yield good impressions, a little white wax should be scraped over the picture, and placing a sheet or two of blotting-paper over the wax, melt it by passing a hot flat iron over it. By this means the wax is absorbed, and the paper becomes more transparent.

Having likewise smoothed the paper which is destined for the positive impression, and which has been prepared, according to our previous directions, with ammoniacal nitrate of silver, and one or other of the muriates, place on the prepared surface, when perfectly dry, the negative picture to be copied, with its face downwards, slightly attaching the one to the other by one or two small particles of wafer fixed at the corners. The two surfaces are then to be pressed into close contact by means of a plate of glass, or in the reversing frame already described, and in this state exposed to the light of the sun or sky, with the back of the negative upwards. The exposed parts of the sensitive paper will speedily darken, and the process should be allowed to proceed some time longer than the shade of tint would lead the operator to suppose, as the colour of the *positive* is slightly lightened by the subsequent fixing. Care must be taken, however, by occasional inspection, not to allow it to proceed so far as to injure the lights of the picture.

The positive copy is then to be fixed, and this is accomplished in the manner already described for fixing the negative. Minute details of the fixing process will be found in Vol. I. p. 605. Any number of positive impressions may be taken. When thus finished, the photograph ought to be preserved from damp and dust, and rather exposed to the light than kept in the dark, otherwise it is apt to fade a little. It is best preserved unimpaired by mounting it in the usual way with a glass in front, or by giving it a coating of gelatine over its surface.

There are other processes, due to Sir John Herschel, Gustave Le Gray, and others, by which the photographic impressions on paper are greatly accelerated and improved. These belong, however, to the art in its more advanced stages; and we shall postpone them until we have described the common Daguerreotype processes, and those in which glass plates are employed. The Daguerreotype will form the subject of our next chapter, and then we shall proceed to describe the processes on glass, which, on account of their simplicity, the cheapness of the few materials employed, and the beauty of the results obtained, has already superseded to a great extent the use of the Daguerreotype for portraits.

THE WROUGHT-IRON BAR-CHAIN SUSPENSION BRIDGE ACROSS THE DNIEPER AT KIEFF, IN RUSSIA.

DESIGNED BY CHARLES VIGNOLLES, TRAFALGAR SQUARE, LONDON, AND MODEL EXHIBITED BY HIM IN CLASS VII., NO. 105, OF THE GREAT EXHIBITION.

(*Illustrated by a Plate.*)

Our plate represents the great suspension bridge at Kieff, erected across the river Dnieper, by command of His Imperial Majesty the Emperor of Russia, and finished only in the autumn of last year (1852). It is about half an English mile in length, and 52½ English feet in breadth. The area of the principal roadway or central avenue is 140,000 superficial feet. This bridge is the largest work of the kind hitherto executed.

Although it is little more than a century since iron suspension bridges were first introduced into this country, their antiquity is proved by the very remarkable fact, that travellers in India and Thibet have seen them in these eastern countries much resembling our own in construction. In one instance a bridge of bamboo is stated to be supported on chains, which were raised over stone piers, with openings through them admitting to the gangway. The first iron suspension bridge in this country was constructed in 1741, at which date one of seventy feet span was thrown over the river Tees. The idea was promulgated in Europe at an earlier period by Scamozzi, in his work, "Del Idea Archi," published in 1615; but the true principles of their construction were first explained by Bernouilli. The roadways of suspension bridges must not merely be hung from the chains, but must be rendered sufficiently stiff to resist the undulatory motion caused by the wind; and more especially is this precaution required when the span is of considerable extent. The first large bar chain bridge erected in Britain was the Union Bridge over the Tweed, 449 feet span, constructed in 1820, by Captain Sir S. Brown, who likewise erected the Newhaven and Brighton suspension piers. Telford's great bridge across the Menai Straits was commenced in May, 1819, and completed in December, 1825; it is 570 feet span. The Hammersmith Bridge, by Tierney Clark, which is 422 feet span, was completed in 1824. The Montrose Bridge was erected by Rendel in 1829, and is 412 feet span. The Hungerford Bridge, over the Thames, by Brunel, is 676½ feet span, and was built in 1844. The wire-rope bridge at Frieburg, which is no less than 820 feet span, was constructed by M. Challey, a French engineer; it cost only £24,000, although a considerable portion of the iron was imported from England; the wire was drawn at Bienne, from iron forged in the Canton of Berne.

The channel of the river Dnieper at the bridge at Kieff, of which our plate is an engraving from the model of C. Vignolles, Esq., is about the depth of 35 feet in summer, but the spring floods increase it to 50 and sometimes to 55 feet. To provide a passage for the navigation, the chains on the right or Kieff side of the river are moored in an isolated abutment, built at a sufficient distance from the shore to allow vessels to pass. This is accomplished by a drawbridge, 52½ feet in breadth, spanning an opening of 50 feet. The whole weight of the drawbridge is about 150 tons; it revolves in one leaf, and centres like a railway turntable, the counterpoise required being very small. The supports are hollow beams of wrought-iron, about 130 feet long.

The foundations of the bridge are on piling and concrete. Eight coffer-dams were required for getting the foundations laid; and ten steam-engines, two of 50-horse power each, were employed on the works. The piers and abutments are of brick, faced with granite; about 1000 tons of granite ashlar are inserted in each abutment, as an extra mass for the mooring-plates of the chain to bear upon. The granite was conveyed from a distance of nearly 100 English miles, across a country destitute of hard roads. The hydraulic cement employed was the artificial preparation recommended by Vicat, the celebrated French engineer.

There are five river piers; and the four principal suspension spans between them are each of 440 English feet. Each chain, extending over the five piers and through the two abutments, is more than half an English mile in length. The wrought-iron rods by which the platforms are suspended from the chains are two inches diameter. On the principle already stated, the roadway is made peculiarly stiff, to resist the undulatory action of the wind, and the various strains from other causes to which it is subject.

The iron-work was entirely manufactured in England; the chains by Fox & Henderson, Birmingham. The total quantity employed in this great work, including the machinery used, was 3,500 English tons. No less than sixteen vessels were employed in transporting this ponderous load of material from Liverpool to the port of Odessa, from which it was conveyed to Kieff, a distance of 400 English miles, on bullock-carts.

About five years were occupied in rearing this gigantic monument of human enterprise; but in consequence of interruptions from the climate, and other circumstances, not more than 100 working-days in each year were available for carrying on the principal and more difficult parts of the work. The cost of the bridge is stated to amount to about £400,000 sterling.

NATURAL PHILOSOPHY AND CHEMISTRY.

CHAPTER XXIV.

ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART II.—ELECTRO-MAGNETISM—*Continued.*

34. THE nearer the conducting-wire is brought to the needle, the greater will be the disproportion between the arcs A S B, C N D, in which the tangential forces oppose each other; and the arcs A D, B C, in which these forces concur. It has been already stated, in our explanation of the action of a descending current upon one pole of a magnet, that there are two points in the circle at which the needle attains a state of equilibrium; namely, those points where the needle is perpendicular to lines drawn from the conducting-wire W to those parts of the circle where they form tangents to the circle, (see sect. 25.) In the case of the action of the current upon both poles of the needle, it follows that there are two points on each side of a line drawn from the conducting-wire, and bisecting the circle, between which the opposition of the tangential forces, explained in section 32, will prevail; namely, those points in the circle cut by the magnet, when one of its poles occupies either of the positions of neutrality before alluded to. For instance, if we refer to fig. 6, it will be seen that B S, and S D, corresponding to S O, and O N′, in the annexed figure, show the two positions of equilibrium; for, in these positions, the needle is at right angles to the lines W N′, and W S, drawn from W, and forming tangents to the circle; but S N, and S′ N′ in fig. 11, represent two different positions of both poles of a magnet, N S, supported by a central pivot; and in each position one of these poles occupies the position of equilibrium. It will be apparent, therefore, that the arcs of the circle S′ S, and N′ N, thus formed by the two positions of the needle in the lines of equilibrium, are those arcs within which the contrary tangential forces occur; and that, from what has been already stated in sections 26 and 29, in the larger and remaining arcs S′ A N, and S B N′, the poles of the needle move in contrary directions. It will now be perceived more clearly how it is that the approach of a conducting-wire W to the circle in which the needle is supposed to revolve, has the effect of diminishing those arcs of the circle where the tangential forces concur, and of increasing those where they oppose; for, in proportion to the diminution of the distance between the wire and the circle, so is the diminution of the lines drawn as tangents from W to that circle; and, therefore, the lines of equilibrium, which must be perpendicular to those tangents, must gradually approach each other, until, at length, on the contact of the conducting-wire with the circle, they unite, and, as a consequence, the neutral points vanish.

Fig. 10.

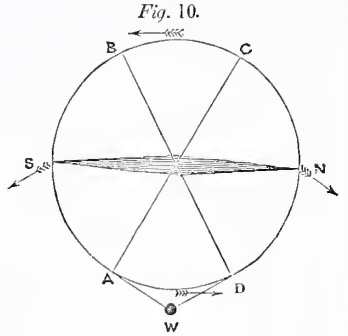
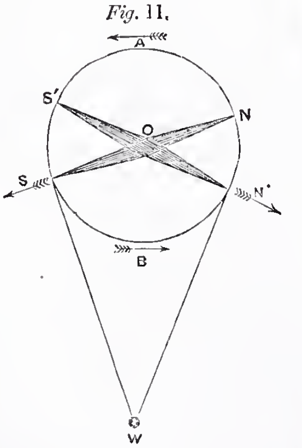


Fig. 11.



35. When the conducting-wire passes through the circumference of the circle, the needle will appear to be totally uninfluenced by it; for, although, when the needle varies from the position it occupies in fig. 10, the two poles will be at different distances from the wire, and the intensity of the forces acting thereon—being inversely as the distances—will differ considerably; still, in those arcs of the circle where the tangential forces concur, the difference in question will not affect the result, and in those arcs where they oppose, the force acting on the nearer pole, being, of course, the greater, will fully compensate for the disadvantage arising from its oblique direction, and will attain an equality with the lesser force which acts with greater mechanical advantage on the remote pole. For instance, in the annexed figure, the force acting upon S, in the direction from A to S, is to the force acting upon N, in the direction A N, inversely as the distances A S, A N; that is, they are as the lines A N, A S; but as the force A S acts by the lever C B, and the force A N by the lever C D, which are in the same proportion, they must be in perfect equilibrium, according to the laws of statics. Or, in other words, the forces A S and A N, when united, give the force A W as their resultant, which, from its being directed to the centre of motion C, has no power to produce rotation. This principle holds good, no matter what may be the position of the needle in the circumference. When the conducting-wire is within the circle, as in fig. 13, this state of equilibrium no longer obtains, for there is no one position of the needle in which the two forces combine to cause rotation in the same direction; in fact, they are opposed to each other in every part of the circle. There is only one position in which a stable equilibrium can be found; namely, that at N S, in the annexed figure; and here, it will be observed, that the poles of the needle are differently situated to what they are in the figs. 9 and 10, where the needle is external to the circle; for, in the present instance, the north pole is to the left, and the south to the right of the conducting-wire, which is the reverse of their former positions. When the needle is moved from this position, and placed in that, for example, of *n′ s′*, the force acting upon *n′*, which is nearest the wire, exceeds that which acts upon *s′*, which is more remote, and therefore the needle will be drawn back to its former position N S; but, if the pole N be placed on the opposite side of the wire, the tangential force which impels it towards the wire, is more powerful than that which influences the opposite pole, and induces it to move in a contrary direction. For this reason, the needle moves towards the wire, and remains in contact with it, being unable to pass the obstruction presented by its substance. However, if the

Fig. 12.

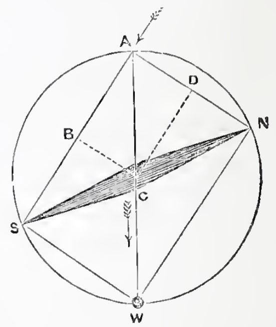
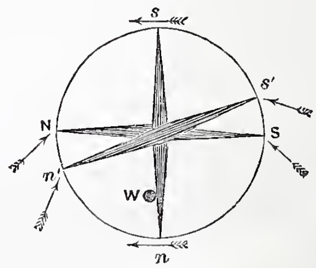


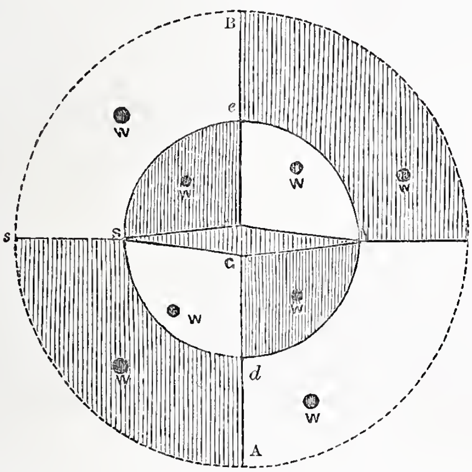
Fig. 13.



same pole of the needle were carried to a greater distance from w, but still at the same side, the excess of the attractive force would gradually diminish, and at length cease, when the needle attained the same transverse position as at first, with this difference, that the pole N, which before was at the left side of the conducting-wire, is now on its right, and a state of equilibrium is again attained; but, in this case, an unstable one; for, if N be further withdrawn from w, the force influencing S attains the superiority, and the needle is turned round until its motion is stopped by its striking against the conducting substance.

36. The reader will observe, that many of the movements of the poles of a magnetic needle towards and from a conducting-wire, as described in the preceding sections, have the appearance of arising from simple attraction and repulsion; but it is proper that results apparently similar, and apparently produced by the same cause, should not be confounded; for, upon close observation, it will be perceived that the simple attractive, or repulsive influences exercised between two substances, are quite incapable of accounting for the sudden transition from attraction to repulsion, caused by the least variation in the relative positions of the conducting-wire and magnet. As it is of the utmost importance to comprehend thoroughly the varying effects of the changes of position of the needle in relation to the conducting-wire, and the nature of the operation of the tangential forces in their varying positions, the reader is referred to the following figure, which gives a general view of the various results attending change in the position of a vertical conducting-wire w, in which the current is supposed to be descending:—

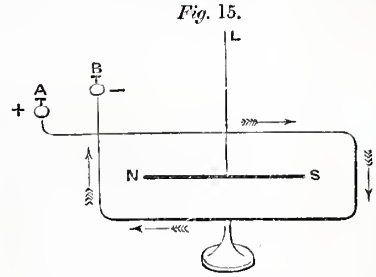
Fig. 14



37. In this figure the boundaries between the positions of apparent attraction and repulsion, are represented by the circumference of the circle of which the needle S N forms a diameter—by the axis of that needle prolonged at each end, and by a line passing at right angles over the centre of the needle. The circumference of the circle denotes the positions of the conducting-wire when no perceptible influence is exercised on the needle; in other words, the positions of neutrality. When the wire is in any part of the two portions of the line B A, which lie between C *e*, and *d* A, the equilibrium of the needle in its transverse position will be stable; when in any part of the remaining portions unstable. The four unshaded divisions in the figure show the spaces within which, in any part, apparent attraction occurs between the wire and the nearest pole; the shaded divisions show those spaces, within which apparent repulsion occurs between the nearest pole and w. For instance, within the unshaded quadrant N C *e*, there is apparent attraction of the pole S; in the shaded quadrant N C *d*, there occurs apparent repulsion of the same pole; the wire apparently repels the pole N in the shaded quadrant *e* C S; and in S C *d*, it apparently attracts it. The apparent influences in the spaces beyond the circumference are the reverse of those within it; for instance, in the shaded space *s* S *d* A, the influence of w upon the pole S is apparently repulsive; in the unshaded space adjoining *s* S *e* B, the contrary influence appears to operate upon the same pole; when w is in B *e* N *n*, apparent attraction affects the north pole, and when in the remaining unshaded portion that pole seems to be repelled. When the current in the wire is ascending, all these actions are reversed; repulsion occurring where attraction before prevailed, and attraction where repulsion.

38. From what has been stated, the reasons for constructing the galvanometer of a rectangular form, will now be sufficiently obvious. If we suspend a magnetic needle (by a line attached to its centre) within a conducting wire, bent into the form of a rectangle, the longest sides of which shall be parallel to that needle, as in the annexed figure, we shall perceive that the actions of the current when moving along the wire horizontally, and downwards and upwards, will all tend to produce the same effect upon the motion of the needle; that is to say, the different lines of direction of the current will influence similarly the poles of a magnet pointing naturally north and south, so as to produce rotation in the same direction until a position of equilibrium is attained. For instance, if the current enters at A, and, passing along the wire in the direction of the arrows, passes out at B, the separate influence of each side of the conducting wire according to the principles previously developed, will impel the pole N eastward, and the pole S, to the west; the needle will therefore tend to assume a transverse position to the wire, approaching more nearly to a right angle, according to the force of the current which that wire conducts.

Fig. 15.



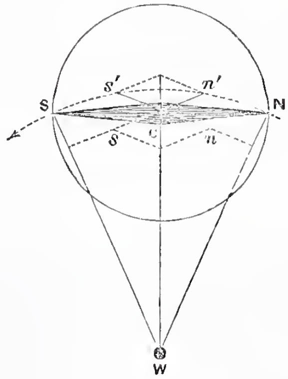
39. If the current passing along the rectangular wire have the last mentioned property of causing deviation of the north pole of a suspended needle to the right, it follows that the needle, so influenced, will give a contrary impulse to the rectangle, supposing it to be also possessed of freedom of motion. This may be exhibited by an ingenious modification of the foregoing arrangement, in which the lower horizontal wire of the rectangle is divided in the centre, and a small portion of the divided ends turned downward at right angles to their former position, and passed through a piece of cork floating in a vessel of acidulated water. A small plate of zinc is connected with one end of the wire after passing through the cork, and a plate of copper with the other;—a floating voltaic battery is thus constructed, from which the current passes along the rectangular wire as before. The needle is similarly suspended within the rectangle; and thus, both wire and needle having perfect freedom of motion, as soon as the influence of the passing current causes deviation of the north pole towards the right, the influence of that pole will turn the rectangle towards the left. This simple arrangement will be found a useful modification of the apparatus invented by De la Rive, and will exhibit various other phenomena of apparent attraction and repulsion, all of which may be explained by means of the principles already developed.

40. It has been already stated (section 33), that if the magnetic needle were unrestrained by its central pivot, the resultant of the equal forces which preserved it in a state of stable equilibrium from its passing through the centre of motion, would not have any effect in producing rotation; but when applied at that point, would, under certain conditions, incline the centre of the magnet and conducting wire towards,

and under other conditions, from each other. These facts now require further explanation. The reader's attention has been hitherto directed to the effects of the electric force on a magnetic needle so restrained as to its centre, as to be capable only of circular motion round that centre; but it would be found that if the needle had unrestrained liberty of motion, a portion of the forces acting on its poles, would tend to displace the whole needle, by causing motion of its centre as well as of its circumference. So long as the needle rests on its pivot, the influence of this force is only exerted by pressure of the needle on some one side of the pivot; but upon freeing the needle from this restraint, the operation of the force will then become apparent, and the direction and amount of the motion of the centre of the needle may be estimated by the amount and direction of the resultant force.

41. For instance, if we suppose a line from the conducting wire W, in the adjoining figure, to cut the centre of the horizontal needle S N, at right angles to its axis; the needle, as before stated, will be in equilibrium, being acted upon by equal tangential forces in opposite directions, (section 32.) If the force thus acting at S, be supposed to be transferred from the pole to the centre, still preserving the same direction, and the force at N to be similarly transferred, we shall have as the resultant of these two equal forces, a single force, which may be represented by the diagonal of a parallelogram two of whose sides are the transferred levers of force, C s and C n, and the diagonal itself being in the line drawn from W to the needle, and the sides of the parallelogram being therefore equally inclined thereto, the force will be such as to impel the centre of the needle in the line of the diagonal toward W, that is, it will give it the appearance of being attracted; but if, in place of the current being a descending one, or if being ascending, the wire conveying it be removed to the opposite side of the needle, or if the direction of the current being unchanged, the needle itself be reversed, so that its north pole shall occupy the position of its south, then, in any of such cases, the tangential forces in place of being divergent, will be convergent, that is, the arrows will point towards the lines connecting W with the pole of the needle, showing an opposite direction of the forces, which in such case will be represented by C s', C n', forming two sides of a parallelogram whose diagonal forms a continuation of the central line W C, at the opposite side of the needle, manifesting a motion of that centre from the conducting wire W, and resembling repulsion.

Fig. 16.



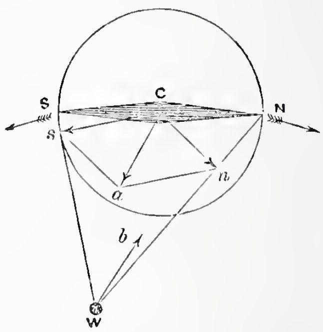
42. It will appear from what has been already stated, that as the distance between the needle and the conducting wire is increased, so is the intensity of the force which acts upon the needle diminished. One reason is, that the compound forces themselves are inversely proportional to the distance of the points on which they act from the wire; and the other is, that the angles they form with each other become more obtuse in proportion to the augmentation of that distance. For example, if a magnetic needle be suspended by a thread from its centre, so as to be balanced horizontally, upon advancing it towards a vertical conducting wire along which a current is descending, it will so place itself as that its north pole will be on the right, and its south on the left of the conducting wire, when suspended at the remote side of the wire; but the position will be reversed, if it be placed between the spectator and the descending current. In either case, the needle will move towards the wire, which will be manifested by the inclination from the perpendicular of the thread by which it is suspended.

43. When the needle is suspended at a great distance from the descending current, the tendency of its centre to approach the wire will be scarcely perceptible, in consequence of the angle formed by the lines indicating the directions of the equal forces being nearly equal to two right angles; but, in this case, if it be carried round the wire while the same distance is preserved, its poles will adjust themselves to the direction in which the tangential force impels them to move around the circumference of a circle of which the conducting wire is the centre.

44. If the wire be placed in any part of the circumference of a circle of which the needle forms a diameter, the line representing the resultant of the two forces having a direction more or less oblique to the axis of the needle, a part of the force acting in that line is applied in moving the needle in the direction of its length, and in bringing the centre opposite to the conducting wire, so that it will continue in motion until that centre touches the wire. A similar disposition in the centre of the needle to approach the wire occurs in all other positions of the wire on the same side of the needle; but the resulting movement of the centre has a direction more or less oblique to the line uniting the wire to the centre of the needle.

45. It has been already stated, that the actions between the conducting wire, when free to move, and the poles of the needle, are reciprocal; that is to say, the wire is impelled by a force equally intense, and parallel in its direction to the resultant force which acts upon the centre of the needle; therefore the determination of this force will also give the amount and direction of the resultant of the forces which influence the wire; for instance, if the needle S N, (fig. 17), be actuated by a force represented by C a, the conducting wire, W, will also be actuated by a similar force, represented by W b, equal and parallel to C a, but acting in a contrary direction.

Fig. 17.



MATHEMATICS.

PRINCIPLES OF ALGEBRA.

Chapter V.—Simple Equations of Condition.

49. *Definition.*—An equation of condition is one which is true only for certain values of the letters. For instance, the equations $x + 1 = 9$, and $y - 4 = 6$, are true only on the *condition* that x is 8, and that y is 10. The expressions between which the sign $=$ is placed are called the *members* or *sides* of the equation, and the individual quantities are called its *terms.*

An equation of condition, containing a letter the value of which is unknown, is said to be *solved* when that number for which the unknown letter must stand in order that the equation may be true, is determined; and the particular number which may be put for the unknown quantity, and the equation remain true, is said to *satisfy* the equation.

In order to distinguish an unknown quantity from others, it is commonly denoted by one of the last letters of the alphabet, whilst known quantities, if not expressed in numbers, are denoted

by the first letters of the alphabet. Where there is only one unknown quantity, it is usually denoted by x, and to effect a solution of the given equation is to find the number which it denotes. In the operations for that purpose we shall have occasion to make use of the following self-evident truths:

I. If to two equal numbers we add the same number, the sums will be equal.

Thus, if $p = q$, then will $p + a = q + a$.

II. If from two equal numbers the same number be subtracted, the remainders will be equal.

That is, if $p = q$, then $p - a = q - a$.

To illustrate these axioms, let it be required to find the value of x, which will satisfy the equation

$$4x - 4 = 3x + 3.$$

If we add 4 to each of these equal quantities, we get

$$4x - 4 + 4 = 3x + 3 + 4 \text{ ; that is } 4x = 3x + 7.$$

Subtract now $3x$ from both of these last, and the equation becomes

$$4x - 3x = 3x - 3x + 7, \text{ that is } x = 7.$$

To prove whether 7 be the true value of x, let us substitute that number for x in both sides of the given equation; if the numbers have the same numerical value, then must 7 be the true value of x. The process is called *verification.*

$$\text{If } x = 7, \text{ then } 4x - 4 = 4 \times 7 - 4 = 24$$
$$\ldots\ldots 3x + 3 = 3 \times 7 + 3 = 24.$$

50. The preceding axioms enable us to apply the rules of addition and subtraction in the solution of equations; the following extend these rules to multiplication and division; namely,

I. If two equal numbers be multiplied by the same number, the products will be equal numbers.

That is, if $p = q$, then is $mp = mq$.

II. If two equal numbers be divided by the same number, the quotients will be equal numbers.

That is, if $p = q$, then is $\frac{p}{m} = \frac{q}{m}$.

From these principles it immediately follows that, *If both members of an equation be either both multiplied or both divided by the same quantity, the results will still be equal.*

To illustrate this, let it be required to find the value of x which will satisfy the following equation,

$$12x - 23 = 7 + 2x.$$

Adding 23 to each side of the equation, and reducing, we get

$$12x = 30 + 2x.$$

Subtracting $2x$, and reducing, this last becomes

$$10x = 30.$$

Now, if we divide both these equal quantities by 10, the coefficient of x, we find $x = 3$.

Verification.—If $x = 3$, then $12x - 23 = 13$ and $7 + 2x = 13$.

51. In the solution of equations we do not formally apply the axioms in Art. 49, but use the abridged principle as expressed in the following

Proposition.—Any term of an equation may be removed from one member and placed in the other with a contrary sign. This is nothing more than a convenient mode of applying the principle expressed, by saying that two equal quantities are still equal when equally increased or diminished; for,

$$\text{Let } ax - b = cx + d$$
$$\text{Add } b, \text{ then } ax = cx + d + b$$
$$\text{Sub. } cx, \text{ then } ax - cx = d + b,$$

in which the terms cx and b are upon different sides with opposite signs, and might have been so placed at once by application of the proposition.

The operation of removing terms at once from one side of an equation to the other, is called *transposition.* The following are instances of its application:—

Given Equations	Obtained by transposition.	Value of x
$3x + 9 = 2x + 12$	$3x - 2x = 12 - 9$	$x = 3$
$7x - 8 = 6x - 2$	$7x - 6x = 8 - 2$	$x = 6$
$20 - 3x = 22 - 4x$	$4x - 3x = 22 - 20$	$x = 2$

51. By means of the axioms in Art. 50, we are able to transform an equation, which contains fractions, into one having all its terms expressed in an integral form.

$$\text{Let } \frac{1}{2}x + \frac{1}{3}x = \frac{3}{4}x + \frac{5}{8}.$$

Multiply every term of this equation by a common multiple of the denominator of the fractions, that is, by $3 \times 8 = 24$, (for the 2 and 4 are manifestly included in 8; (see 3° Art. 35, p. 160,) then wo get

$$12x + 8x = 18x + 15$$
$$\text{whence } x = 7\tfrac{1}{2}$$

The operation of reducing an equation, containing fractional terms, to an integral form, may then, it appears, be performed by multiplying both numbers by any common multiple of all the denominators; generally, the least common multiple is the most convenient.

52. We have already defined an equation of condition, (Art. 49,) and when the term equation is used without any qualification, it is always to be understood to signify an equation of the nature there stated. There are, however, various classes of equations of eondition; those which contain only the first power of the unknown quantity are said to be of the *first degree,* and are commonly called *simple equations.* All the equations which have hitherto engaged our attention pertain to this class, and have only one value of the unknown quantity; whereas those equations in which higher powers of the unknown quantity are found, are satisfied by more than one value. For instance, the equation

$$3x - 5 = 2x + 2,$$

is true only when x is 7; but the equation

$$2xx + 3 = 7x,$$

is true when $x = 3$, and also when $x = \frac{1}{2}$, but in no other case.

The difficulty of solving equations depends upon the degrees of the equation and the number of the unknown quantities; we shall therefore take the cases in the order of their difficulty, premising that equations of the first and second degrees are of most frequent occurrence in the practical applications of algebra.

§ I. Of Simple Equations containing only One Unknown Quantity.

53. As the unknown quantity in equations coming under this head, is necessarily of the first degree, and as it can be combined with the known quantities only by addition, subtraction, multiplication, and division, the principles already explained and exemplified in the preceding articles are amply sufficient for their solution; but before translating these principles into a general rule, we shall briefly exhibit them in algebraical language. For that purpose, let X and P be the members of an equation in its unreduced form,

$$\text{that is, let } X = P$$

Then by Art. 49, the equation still exists when X and P are both of them increased or diminished by the same quantity, and consequently by any two quantities which are reducible to identity with each other. Thus, the above equation being true, the following are true:

$$X + A = P + A \qquad X - A = P - A$$

And if $A = B + C$ then will the following equations be also true

$$X + A = P + B + C \qquad X - A = P - B - C$$
$$X + C = P + A - B \qquad X - C = P - A + B$$

It is in eonsequence of this proposition that quantities may be *transposed* from one side of an equation to the other, by merely changing their signs from + to — or from — to + (See Art 51.)

Thus, if the primitive equation be $X - A = R$, by adding A to both members we get

$$X - A + A = R + A \qquad \text{or} \qquad X = R + A$$

Similarly, if $X = R + A$, by subtracting A from both sides we get

$$X - A = R + A - A \qquad \text{or} \qquad X - A = R$$

From this it follows that every equation admits of such a modification of its form that all its significant terms may be made to form one of its members and zero the other: for if

$X = P$, by subtracting P, we get $X - P = 0$

Again by Art. 50 the equation will continue to exist when X and P are both of them either multiplied or divided by the same quantity or by quantities which are identical with each other, thus:

$$\text{If } X = P, \text{ then } AX = AP, \text{ and } \frac{X}{A} = \frac{P}{A}$$

And if $A = B + C$, the following equations are likewise true,

$$AX = BP + CP \qquad \frac{X}{A} = \frac{P}{B + C}$$

It is in consequence of this proposition that we are able to clear an equation of fractional terms (exemplified in Art. 51), and to free the unknown quantity of its coefficient, when we have succeeded in bringing the equation under the form $ax = b$; where b is the product of x multiplied by a, and therefore $x = \frac{a}{b}$

54. From these principles we derive this rule for the solution of simple equations containing only one unknown quantity:

1° *Clear the equation of fractions. (Art. 51.)*
2° *Transpose the terms involving the unknown quantity to one side, and those which do not involve it to the other.*
3° *Collect the separate terms in that member of the equation which involves the unknown quantity into one term.*
4° *Divide both members of the equation by the coefficient of the unknown quantity.* This gives the solution required.

The following are preliminary instances of the application of this rule to numerical equations, reference being made to the rule by means of the numbers 1°, 2°, 3°, 4°.

Example 1. Given $x + \frac{3x - 5}{2} = 12 - \frac{2x - 4}{3}$

By 1° $\quad 6x + 3(3x - 5) = 72 - 2(2x - 4)$
By 2° $\quad 6x + 9x + 4x = 72 + 8 + 15$
By 3° $\quad 19x = 95$
By 4° $\quad x = \frac{95}{19} = 5$

Verification. If $x = 5$

$$x + \frac{3x - 5}{2} = 5 + \frac{15 - 5}{2} = 10 \qquad 12 - \frac{2x - 4}{2} = 12 - \frac{10 - 4}{3} = 10$$

It is often advantageous before commencing the solution to simplify an equation by performing the more obvious operations indicated among the terms. The following is an instance.

Example 2. Given $5x + \frac{7x - 1}{2} - \frac{x - 1}{4} = \frac{5x + 11}{6} + \frac{11x + 15}{2}$

$$\text{Here } 5x + \frac{7x - 1}{2} - \frac{x - 1}{4} = \frac{20x + (14x - 2) - (x - 1)}{4} = \frac{33x - 1}{4}$$

$$\text{And } \frac{5x + 11}{6} + \frac{11x + 15}{2} = \frac{(5x + 11) + (33x + 45)}{6} = \frac{19x + 28}{3}$$

$$\text{Therefore } \frac{33x - 1}{4} = \frac{19x + 28}{3}$$

By 1° $\quad 99x - 3 = 76x + 112$
By 2° $\quad 99x - 76x = 112 + 3$
By 3° $\quad 23x = 115 \quad \therefore$ by 4° $\quad x = 5$

Verification. If $x = 5$; $\frac{33x - 1}{4} = 41 \qquad \frac{19x + 28}{3} = 41$

If the same quantity be found on both sides of an equation and have the same sign, it may be omitted. The following is an instance.

Example 3. Given $\frac{4x + 3}{9} + \frac{7x - 29}{5x - 12} = \frac{8x + 19}{18}$

$\times (18) \qquad 8x + 6 + \frac{18(7x - 29)}{5x - 12} = 8x + 19$

$-(8x + 6) \qquad \frac{126x - 522}{5x - 12} = 13$

$\times (5x - 12) \qquad 126x - 522 = 65x - 156$

By 2° and 3° $\qquad 61x = 366$

$\therefore$ By 4 $\qquad x = 6$

Verification. If $x = 6$; $\frac{8x + 19}{18} = \frac{48 + 19}{18} = \frac{67}{18}$

$$\frac{4x + 3}{9} + \frac{7x - 29}{5x - 12} = \frac{27}{9} + \frac{13}{18} = \frac{67}{18}$$

55. The rule for the solution of numerical equations is precisely the same as when the equation is given in general terms. We subjoin an example of a general nature, the letters a, b, c, d, and so on, being used to denote known quantities, that is quantities of which we are supposed to know the numerical values.

Example Let $\quad ax + b = cx + d$
By 2° $\quad ax - cx = d - b$
By 3° $\quad (a - c)x = d - b$
By 4° $\quad x = \frac{d - b}{a - c}$

Verification. $ax + b = a\left(\frac{d - b}{a - c}\right) + b = \frac{ad - ab + ab - bc}{a - c} = \frac{ad - bc}{a - c}$

$cx + d = c\left(\frac{d - b}{a - c}\right) + d = \frac{cd - bc + ad - cd}{a - c} = \frac{ad - bc}{a - c}$

56. *Errors of Process.*—In applying 2° of our rule, we have uniformly collected those terms of the equation containing the unknown quantity into the first member. This we do for convenience and by convention; but let it be attempted to solve the following equation, on the assumption that it is essentially necessary to adopt this arrangement. The equation is

$x + 4 = 2x + 1 \quad$ whence by 2° $\quad x - 2x = 1 - 4$

Here we have two impossible subtractions $x - 2x$ and $1 - 4$; but let the transposition be made to the contrary sides, and we obtain

$4 - 1 = 2x - x \quad$ from which we get $\quad 3 = x$

This shows that our mode of reduction, and the disposition of the members of the equation are at variance, and that, if we would collect the terms containing x into the first side, we ought to have written

$2x + 1 = x + 4 \quad$ instead of $\quad x + 4 = 2x + 1$

But as we cannot in all cases pronounce before commencing the solution of an equation, that the members are disposed in conformity with our method of reduction, and as it would not always be convenient, when we had discovered that they were not, to retrace the steps of the process gone through, it becomes necessary to have some way of rectifying the mistake. This we readily obtain by an extension of our rule for transposition: for if

$a - nx = mx - b$ be true $\quad mx - b = a - nx$ is true.
$b - nx = mx - a \quad . \; . \; . \quad mx - a = a - nx \; . \; . \; .$
$b - mx = nx - a \quad . \; . \; . \quad nx - a = b - mx \; . \; . \; .$

But $nx - a = b - mx$ is the given equation $a - nx = mx - b$ with all its signs changed. Let both be solved, collecting the terms containing x in contrary sides:

from $\quad nx - a = b - mx \quad$ from $\quad a - nx = mx - b$
we get $(m + n)x = a + b \quad$ we get $a + b = (m + n)$

$$\therefore x = \frac{a + b}{m + n} \text{ in both.}$$

From this it appears that equations composed of the same terms with contrary signs give the same answer, and hence we conclude generally that

If the sign of every term of an equation be changed from

+ to — or from — to + the new members will still be equal to each other, and give the same answer, as if the signs had not been changed. This is nothing more in effect than the transposition of every term of the equation.

It is true that if this be done with such equations as $a\,x + b = c\,x - a$ in which all the terms of one member are positive, they will, from being just, become apparently absurd; and in those cases in which some of the terms are positive and others negative, if the equation be at first justly stated, it will be found on attempting to verify the altered equation by the result of the solution, that impossible subtractions are introduced, and that the process is in consequence irrational. For instance,

The given equation is	The altered equation is
$4x - 150 = 3x - 100$	$150 - 4x = 100 - 3x$
which gives $x = 50$	which gives $50 = x$
Rational: $200 - 150 = 150 - 100$	*Irrational:* $150 - 200 = 100 - 150$

The irrational expressions show that the equation from which they result is incorrectly written, and that its signs require to be changed. We shall hereafter return to the discussion of expressions of this sort.

57. Another error of process arises in this way: If we have $a - b + c$ and wish to bracket b and c together, we cannot do this with certainty until we know which is the greater. If we know that b is the greater, then we write $a - (b - c)$, but if c be the greater, the correct expression is $a + (c - b)$. Now one or other of these expressions is incorrect, (except only when $b = c$ which makes them $a - 0$ and $a + 0$, or a for both); yet we know from the rules for addition and subtraction that

$$a + (c - b) = a - (b - c) = a - b + c$$

and consequently that any mistake which amounts to no more than writing $a - (b - c)$ for $a + (c - b)$ will make no difference of the final result. The following instance will show how this happens:

$$x - \frac{a - x}{b} = 1 + \frac{x - b}{c} \qquad x + \frac{x - a}{b} = 1 - \frac{b - x}{c}$$

$$\text{And } x = \frac{a\,c - b\,b + b\,c}{b c + c - b} \text{ in both.}$$

Let now $a = 4$; $b = 3$; and $c = 2$; then will $x = \frac{5}{5} = 1$. On attempting to verify the equations by substituting for the letters their numerical values, we find that $x - b$ in the first, and $x - a$ in the second, are impossible, and consequently, on the assumption of the values stated, the true equation is

$$x - \frac{a - x}{b} = 1 - \frac{b - x}{c} \text{ which also gives } x = \frac{a\,c + b\,c - b}{b\,c + c - b}$$

§ II.—Problems which produce Simple Equations.

58. An *Arithmetical* Problem is one in which numbers are given and the operations to be performed upon them. The question asked is simply what number will result from performing given operations upon given numbers. For instance, what is the twelfth part of the product of 71 and 96? An *Algebraical* Problem, on the other hand, is one in which numbers are either given, or supposed to be given, and a question is asked for which the operations necessary to furnish the answer are not specified. For instance,

Problem I. What number is that to which if 100 be added, the result will be 1000 diminished by 99 times that number?

Here the questions asked are the following: 1. Is there such a number? 2. If there be, by what operations upon the given numbers may it be found? 3. What is the result of these operations, or what is the number? Assuming that there may be such a number, then by the conditions specified

The number + 100 = 1000 — 99 times *the number*

and if x be put to represent the number sought, these conditions will be expressed by

$$x + 100 = 1000 - 99\,x$$

and solving this equation by the ordinary rules, we obtain

$$x = \frac{1000 - 100}{100} = 9$$

Verification. $9 + 100 = 109 = 1000 - 99 \times 9 = 1000 - 891 = 109$

It appears then that there is such a number; that it is found by dividing the difference of 1000 and 100 by 100; and that in consequence the number is 9.

If it be inquired simply by what operations on the given numbers, the number sought may be obtained, it will be unnecessary to specify 99, 100, and 1000, for the same problem might clearly be proposed about any other numbers without in any way changing the process of solution. Let the problem have the following general form.

What number is that to which if a be added, the result will be b diminished by c times that number?

Putting x for the number as before, the conditions are expressed by

$$x + a = b - c\,x \quad \text{whence} \quad x = \frac{b - a}{c + 1}$$

Ver. The number increased by a is $\frac{b - a}{c + 1} + a = \frac{a\,c + b}{c + 1}$

b diminished by c times the number is $b - c\left\{\frac{b - a}{c + 1}\right\} = \frac{a\,c + b}{c + 1}$

Here $\frac{b - a}{c + 1}$ is not strictly speaking the value of x but the arithmetical rule by which all problems of the same nature may be solved. It besides informs us in what cases the problem is impossible; for the expression $b - a$ is impossible unless b be greater (or at least not less) than a. This was the case in the problem given, where $b = 1000$ and $a = 100$; but if it be required to find a number such that being increased by 1000, it will be equal to 100 diminished by c times the number; the impossible subtraction $b - a = 100 - 1000$ shows that there is no such number, and that the problem in consequence involves a contradiction. This is obvious in the case stated, but instances occur in which the reason of the impossibility itself becomes a problem of importance.

Problem II. To find a number such that the sum of its third and fourth parts shall make 63.

Let x denote the number;

$$\text{then } \frac{1}{3} \text{ of } x \text{ is } \frac{x}{3} \text{ and } \frac{1}{4} \text{ of } x \text{ is } \frac{x}{4}.$$

And the condition is

$$\frac{x}{3} + \frac{x}{4} = 63 \text{ whence } x = \frac{12 \times 63}{7} = 108.$$

Verification. $\frac{1}{3}$ of $108 + \frac{1}{4}$ of $108 = 36 + 27 = 63$ as required.

Generalized.—What is the process by which a number may be found such that the sum of its ath and bth part shall be c?

Putting x for the number; the sum of its ath and bth parts is

$$\frac{x}{a} + \frac{x}{b} = c, \text{ whence } x = \frac{a\,b\,c}{a + b}.$$

Verification. $\frac{1}{a} \cdot \frac{a\,b\,c}{a + b} + \frac{1}{b} \cdot \frac{a\,b\,c}{a + b} = \frac{b\,c}{a + b} + \frac{a\,c}{a + b} = \frac{c\,(a + b)}{a + b} = c.$

It appears from this formula that the problem presents no impossible cases.

Problem III. To find a number the double of which falls short of 100 as much as its half exceeds 10.

Let x denote the number. Then will $2\,x$ represent the double of the number and $\frac{x}{2}$ its half. Also $100 - 2\,x$ will express the quantity by which double the number falls short of 100, and $\frac{x}{2} - 10$, the quantity by which its half exceeds 10. But by the conditions of the problem these qualities are equal.

$$\therefore 100 - 2\,x = \frac{x}{2} - 10 \text{ that is } 200 - 4\,x = x - 20$$

Here we have the error of process noticed in Art. 56. Changing the signs therefore, in consequence, we get

$$4x - 200 = 20 - x, \qquad \text{whence} \qquad x = 44$$

Verification. The quantity by which the double of 44 falls short of 100 is 12; and the quantity by which the half of 44 exceeds 10 is also 12.

Generalized. Find a number, the double of which falls short of a (the greater) as much as its half exceeds b (the less).

Reasoning as before, and putting a for 100, and b for 10, we get

$$a - 2x = \frac{x}{2} - b, \qquad \text{or} \qquad \frac{x}{2} - b = a - 2,$$

or changing the signs of this first equation we obtain

$$2x - a = b - \frac{x}{2}, \qquad \text{whence} \qquad x = \frac{2}{5}(a+b).$$

From this value of x it might at first be supposed that the problem presents no impossible case, and that whatever be the numbers proposed, we have simply to take two-fifths of their sum for the number sought. We shall find, however, from the test of verification, that there are conditions attached to a and b which the formula obtained does not contemplate.

Verification. The double of $\frac{2}{5}(a+b)$ is $\frac{4}{5}(a+b) = \frac{4}{5}a + \frac{4}{5}b$

This falls short of a by $a - \left(\frac{4}{5}a + \frac{4}{5}b\right) = a - \frac{4}{5}a - \frac{4}{5}b$ $= \frac{1}{5}a - \frac{4}{5}b.$

Again, the half of $\frac{2}{5}(a+b)$ is $\frac{1}{5}(a+b)$ which exceeds b by $\frac{1}{5}(a+b) - b$;

But $\frac{1}{5}(a+b) - b = \frac{1}{5}a + \frac{1}{5}b - b = \frac{1}{5}a - \frac{4}{5}b$ the quantity by which the double of $\frac{2}{5}(a+b)$ falls short of a. From this we observe that the problem is possible when $\frac{1}{5}a$ is greater (or at least not less) than $\frac{4}{5}b$ or when a is greater than $4b$, and impossihle under all other circumstances. The following is a particular case for exercise :—

Prove that there is no number or fraction, the double of which falls short of 10 as much as its half exceeds 3?

Observe that $10 = a$ and $3 = b$, and that $\frac{1}{5}a - \frac{4}{5}b$ is the excess or defect stated in the conditions. It may, however, be proved independently of the formula stated, that there is no such number: for by the conditions the number sought has a half which exceeds 3, *it must therefore be greater than* 6; and a double which falls short of 10, so that *it must be less than* 5. But a number which exceeds 6 cannot be less than 5; and therefore the clauses of the problem contradict each other.

This problem may be rendered still more general, by requiring to find a number which, being multiplied by m, the result will fall short of a by as much as its nth part exceeds b.

Problem IV.—To find the number from which, if $\frac{1}{8}$ and $\frac{1}{10}$ of itself be subtracted, the remainder is 31.

Let x represent the number. Then $\frac{x}{8}$ and $\frac{x}{10}$ represent $\frac{1}{8}$ and $\frac{1}{10}$ of it; also $x - \left(\frac{x}{8} + \frac{x}{10}\right)$ or $x - \frac{x}{8} - \frac{x}{10}$ is the number with these parts subtracted. Therefore by the question

$$x - \frac{x}{8} - \frac{x}{10} = 31, \qquad \text{whence} \qquad x = \frac{31 \times 80}{62} = 40.$$

Verification. $40 - \frac{40}{8} - \frac{40}{10} = 40 - 5 - 4 = 31$ as required.

Generalized. Put $a = 8$; $b = 10$, and $c = 31$, and the equation expressing the conditions is

$$x - \frac{x}{a} - \frac{x}{b} = c \qquad \text{whence} \qquad x = \frac{abc}{ab - b - a}$$

from which it appears that the problem is always possible when ab is greater than $a + b$, that is, when a and b are respectively greater than 1. *Why?*

Question.—Is there any number which being divided by $\frac{1}{2}$ and by $\frac{1}{4}$, and the quotients afterwards subtracted from it, gives 1 of remainder.

Ans. There is no such number. *Why?*

[That the problem is absurd, may be shown from the nature of fractions: for dividing by $\frac{1}{2}$ and $\frac{1}{4}$ is the same as to multiply by 2 and 4. The problem therefore requires that $2 + 4$ times the number be subtracted from the number itself, and yet leave a remainder, which is absurd.]

Problem V.—A can dig a field in 12 days which it takes B 15 days to dig; in what time can they dig it if they both work together?

Let the time which they take to dig the field together be called x. The fractions of the field which A and B can dig in one day are $\frac{1}{12}$ and $\frac{1}{15}$. Then A, who does $\frac{1}{12}$ in one day, $\frac{2}{12}$ in two days; $\frac{3}{12}$ in three days, &c., will in x days do $\frac{x}{12}$ of the field. In the same time B does $\frac{x}{15}$ of the field. But in x days they will have digged the whole field, and therefore,

$$\frac{x}{12} \textit{ of the field} + \frac{x}{15} \textit{ of the field} = \textit{the whole field.}$$

The magnitude of the field is a quantity which enters as a factor into every term of this equation. Let, therefore, this factor be struck out of every term by division, and we get

$$\frac{x}{12} + \frac{x}{15} = 1 \qquad \text{whence} \qquad x = \frac{12 \times 15}{12 + 15} = 6\frac{2}{3}.$$

Verification. In 1 day A does $\frac{1}{12}$ and B does $\frac{1}{15}$; therefore in 1 day there is done $\frac{1}{12} + \frac{1}{15} = \frac{3}{20}$ and in $6\frac{2}{3}$ days there is done $\frac{3}{20} \times 6\frac{2}{3} = \frac{3}{20} \times \frac{20}{3} = 1$ *which represents a whole.*

Generalization 1. If the time which A takes to dig the field be called a, and the time which B takes be called b, the equation expressing the conditions of the problem is

$$\frac{x}{a} + \frac{x}{b} = 1 \qquad \text{which gives} \qquad x = \frac{ab}{a+b}$$

In this expression for x we observe that a enters into it in the same way as b does; a might therefore be written for b and b for a, without altering its value. Such an expression is said to be *symmetrical* with respect to a and b. This must necessarily be the case from the question; for if A took b days to dig the field, and B took a days, the work would evidently be accomplished in the same time as when A takes a days, and B takes b days. The following are given for exercise.

A power P_1, can produce an effect in 5 minutes, and another power P_2 can produce the same effect in two hours; in what time can they produce the same effect when they act simultaneously? Ans. In 4 minutes, 48 seconds.

How do P_1 and P_2 enter into the calculation?

Ans. Their *product* must be divided by their *sum.*

Generalization 2.—Four agents, A, B, C, and D, can separately produce an effect in the respective times, a, b, c, and d, in what time will they produce it if they all act simultaneously?

Let x denote the time required. Then in the unit of time specified (it may be a day, an hour, or a minute), A, B, C, and D, produce respectively $\frac{1}{a}, \frac{1}{b}, \frac{1}{c}$, and $\frac{1}{d}$ of the effect, consequently in x time they will produce $\frac{x}{a}, \frac{x}{b}, \frac{x}{c}$, and $\frac{x}{d}$ of it. Now these fractions must represent a whole or 1, and therefore the equation is

$$\frac{x}{a}+\frac{x}{b}+\frac{x}{c}+\frac{x}{d}=1 \text{ whence } x=\frac{a\,b\,c\,d}{a\,b\,c+a\,b\,d+a\,c\,d+b\,c\,d}$$

a result which is symmetrical with respect to the four quantities a, b, c, and d, and which may be shown by verification to satisfy the conditions of the problem.

Exercise.—A reservoir is filled by one pipe in 6 hours, by another in $5\frac{1}{4}$ hours, by a third in $2\frac{1}{2}$ hours, and by a fourth in $\frac{1}{8}$ of an hour, in what time will it be filled by the four pipes all running together? Ans. 6 minutes, $51\frac{57}{61}$ seconds.

PROBLEM VI. To find two numbers the sum of which is 83, and their difference 13.

Let x be the *less*, then $x+13$ will be the *greater*, and $x+(x+13)$ their sum. But the sum is 83, therefore the equation for x is

$$x+(x+13)=83 \qquad \text{whence} \qquad x=35$$

Hence the less number is 35, and the greater $35+13=48$. [*Prove that these numbers satisfy the conditions of the problem.*]

Generalized.—Investigate the two numbers which have s for their sum and d for their difference.

Putting x for the *less*, then $x+d$ is the greater, and we have

$$x+(x+d)=s \qquad \text{whence} \qquad x=\frac{1}{2}(s-a)$$

This is the less of the two numbers required; the greater is $x+d$.

$$\text{But } x+d=\frac{1}{2}(s-d)+d=\frac{1}{2}s-\frac{1}{2}d+d=\frac{1}{2}(s+d)$$

Consequently, the numbers which correspond to the problem are

$$x=\frac{1}{2}(s-d) \qquad \text{and} \qquad x+d=\frac{1}{2}(s+d).$$

Verification. $\frac{1}{2}(s+d)+\frac{1}{2}(s-d)=s\frac{1}{2}(s+d)-\frac{1}{2}(s-d)=d$

The following are particular cases of this problem for exercise:

1. A house of two stories is 31 feet in height, and the first story is loftier than the second by $2\frac{1}{2}$ feet; required the height of each story.

Ans. The first story is $16\frac{3}{4}$ feet, and the second is $14\frac{1}{4}$ feet.

Divide a line of 75 inches into two parts in such a manner that the one shall be a foot longer than the other.

Ans. $43\frac{1}{2}$ inches and $31\frac{1}{2}$ inches.

PROBLEM VII. To divide 400 into three parts in such a manner that the difference of the first and second shall be 10, and the difference of the second and third shall be 20.

Let x be the least part; then $x+10$ is the next greater part, and $(x+10)+20$ is the greatest part. But the sum of these parts is 400.

$$\therefore x+(x+10)+\{(x+10)+20\}=400 \text{ whence } x=120$$

then must $x+10=130$ and $(x+10)+20=150$. Therefore 120, 130, and 150, are the parts which the solution gives, and $120+130+150=400$ as required by the problem.

Generalized. Putting $400=a$; $10=b$, and $20=c$; the equation for x is

$$x+(x+b)+\{(x+b)+c\}=a,$$

whence by solution we find that the numbers corresponding to the conditions of the problem are,

$$\frac{1}{3}(a-2b-c) \qquad \frac{1}{3}(a+b-c) \qquad \frac{1}{3}(a+b+2c.)$$

Exercise. Prove by verification that these formulæ satisfy the conditions of the problem. Also solve the following case:

In a granary containing 5000 bolls of grain, there are 900 bolls of oats more than there are of barley, and 1000 bolls of wheat more than there are of oats. How many bolls of each?

Ans. Barley $733\frac{1}{3}$; oats $1633\frac{1}{3}$; wheat $2633\frac{1}{3}$.

PROBLEM VIII.—In the composition of a certain quantity of gunpowder, $\frac{2}{3}$ of the whole *plus* 10 lbs. was nitre; $\frac{1}{6}$ of the whole *minus* $4\frac{1}{2}$ lbs. was sulphur, and the charcoal was $\frac{1}{7}$ of the nitre *minus* 2 lbs. Find the quantity of the powder, and also the quantity of each of the ingredients.

Let $x=$ the number of pounds of *powder*. Then $\frac{2}{3}x+10$ is the *Nitre*; $\frac{1}{6}x-4\frac{1}{2}$ is the *Sulphur*; and $\frac{1}{7}(\frac{2}{3}x+10)-2$ is the *Charcoal*.

But the *Nitre* + the *Sulphur* + the *Charcoal* = the *Powder*.

$$\therefore \left(\frac{2}{3}x+10\right)+\left(\frac{1}{6}x-4\frac{1}{2}\right)+\frac{1}{7}\left(\frac{2}{3}x+10\right)-2=x$$

$$\times(7) \qquad \frac{14x}{3}+70+\frac{7x}{6}-31\frac{1}{2}+\frac{2x}{3}+10-14=7x$$

And by transposition and reduction this equation becomes

$$7x-\frac{13x}{2}=80-45\frac{1}{2}, \qquad \text{whence} \qquad x=69 \text{ lbs.}$$

the quantity of powder. $\therefore \frac{2}{3}x+10=56$ lb. the nitre; $\frac{1}{6}x-4\frac{1}{2}=7$ lb. the sulphur: and $\frac{1}{7}(\frac{2}{3}x+10)-2=6$ lb. the charcoal. Also $69=56+7+6$.

PROBLEM IX.—Several persons enter into a speculation by which they make a profit. Conformable to the agreement, A takes from the common stock £10 and $\frac{1}{6}$ of the remainder; B in turn takes £20 and $\frac{1}{6}$ of the remainder; C takes £30 and $\frac{1}{6}$ of the remainder, and so to the last who takes what is left. The division being made, it is found that each has an equal sum. Required the profit, the number of partners, and the share of each.

Let $x=$ the whole profit. Then, when A has taken £10, there remain $x-10$, the sixth of which is $\frac{x-10}{6}$. His share is therefore $10+\frac{x-10}{6}=\frac{x+50}{6}$ and the remainder is $x-\frac{x+50}{6}=\frac{5x-50}{9}$.

Again, when B has taken £20 there remains $\frac{5x-50}{6}-20=\frac{5x-170}{6}$ the sixth of which is $\frac{5x-170}{36}$. His share is therefore

$$20+\frac{5x-170}{36}=\frac{5x+550}{36}$$

But by the conditions of the question these shares must be equal:

$$\therefore \frac{x+50}{6}=\frac{5x+550}{36}, \qquad \text{whence} \qquad x=£250,$$

the whole profit realized: $\therefore \frac{x+50}{6}=\frac{250+50}{6}=£50$, the share of each; and $\frac{250}{50}=5$, the number of partners in the concern.

59. From these instances, it will be perceived that the main difficulty of answering questions of this sort consists in finding equations to express them. For this no certain rule can be given sufficiently minute and general to meet every variety of enunciation. It may be stated generally, that it is of the first importance to consider attentively the nature of the question, so as to gain a clear perception of its meaning. When this is ac-

quired, a letter x is assumed to stand for the unknown quantity, and *the same operations are performed upon it which would have to be performed upon the number sought, supposing that it were already found, and we wished to ascertain whether it really corresponded to the conditions of the question.* When this is done, an equation is formed, the solution of which gives the required value of the unknown quantity.

THE ELECTRIC CONDUCTION AND THE NATURE OF MATTER.

By Michael Faraday, Esq., D.C.L., F.R.S.

The view of the atomic constitution of matter which I think is most prevalent, is that which considers the atom as a something material having a certain volume, upon which those powers were impressed at the creation, which have given it, from that time to the present, the capability of constituting, when many atoms are congregated together into groups, the different substances whose effects and properties we observe. These, though grouped and held together by their powers, do not touch each other, but have intervening space, otherwise pressure or cold could not make a body contract into a smaller bulk, nor heat or tension make it larger; in liquids these atoms or particles are free to move about one another, and in vapours or gases they are also present, but removed very much farther apart, though still related to each other by their powers.

The atomic doctrine is greatly used one way or another in this, our day, for the interpretation of phenomena, especially those of crystallography and chemistry, and is not so carefully distinguished from the facts, but that it often appears to him who stands in the position of student, as a statement of the facts themselves, though it is at best but an assumption, of the truth of which we can assert nothing, whatever we may say or think of its probability. The word atom,—which can never be used without involving much that is purely hypothetical,—is often *intended* to be used to express a simple fact, but, good as the intention is, I have not yet found a mind that did habitually separate it from its accompanying temptations; and there can be no doubt that the words definite proportions, equivalents, primes, &c., which did and do express fully all the *facts* of what is usually called the atomic theory in chemistry, were dismissed because they were not expressive enough, and did not say all that was in the mind of him who used the word atom in their stead; they did not express the hypothesis as well as the fact.

But it is always safe and philosophic to distinguish, as much as is in our power, fact from theory. The experience of past ages is sufficient to show us the wisdom of such a course; and, considering the constant tendency of the mind to rest on an assumption,—and when it answers every present purpose to forget that it is an assumption,—we ought to remember that it, in such cases, becomes a prejudice, and inevitably interferes, more or less, with a clear-sighted judgment. I cannot doubt but that he who, as a mere philosopher, has most power of penetrating the secrets of nature, and guessing by hypothesis at her mode of working, will also be most careful, for his own safe progress and that of others, to distinguish that knowledge which consists of assumptions,—by which I mean theory and hypothesis,—from that which is the knowledge of facts and laws; never raising the former to the dignity or authority of the latter, nor confusing the latter more than is inevitable with the former.

Light and electricity are two great and searching investigators of the molecular structure of bodies; and it was whilst considering the probable nature of conduction and insulation in bodies not decomposable by the electricity to which they were subject, and the relation of electricity to space, contemplated as void of that which by the atomists is called matter, that considerations something like those which follow were presented to my mind.

If the view of the constitution of matter already referred to be assumed to be correct, and I may be allowed to speak of the particles of matter and of the space between them (in water, or in the vapour of water, for instance) as two different things, then space must be taken as the only continuous part, for the particles are considered as separated by space from each other. Space will permeate all masses of matter in every direction like a net, except that in place of meshes it will form cells, isolating each atom from its neighbours, and itself only being continuous.

Then take the case of a piece of shell-lac, a non-conductor, and it would appear at once from such a view of its atomic constitution that space is an insulator, for if it were a conductor the shell-lac could not insulate, whatever might be the relation as to conducting power of its material atoms; the space would be like a fine metallic web penetrating it in every direction, just as we may imagine of a heap of siliceous sand having all its pores filled with water; or as we may consider of a stick of black wax, which, though it contains an infinity of particles of conducting charcoal diffused through every part of it, cannot conduct, because a non-conducting body (a resin) intervenes and separates them one from another, like the supposed space in the lac.

Next take the case of a metal, platinum or potassium, constituted according to the atomic theory, in the same manner. The metal is a conductor; but how can this be, except space be a conductor? for it is the only continuous part of the metal, and the atoms not only do not touch (by the theory), but as we shall see presently, must be assumed to be a considerable way apart. Space, therefore, must be a conductor, or else the metals could not conduct, but would be in the situation of the black sealing-wax referred to a little while ago.

But if space be a conductor, how then can shell-lac, sulphur, &c., insulate? for space permeates them in every direction. Or if space be an insulator, how can a metal or other similar body conduct?

It would seem, therefore, that in accepting the ordinary atomic theory, space may be proved to be a non-conductor in non-conducting bodies, and a conductor in conducting bodies,—but the reasoning ends in this, a subversion of that theory altogether; for if space be an insulator it cannot exist in conducting bodies, and if it be a conductor it cannot exist in insulating bodies. Any ground of reasoning which tends to such conclusions as these must in itself be false.

In connexion with such conclusions we may consider shortly what are the probabilities that present themselves to the mind, if the extension of the atomic theory which chemists have imagined, be applied in conjunction with the conducting powers of metals. If the specific gravity of the metals be divided by the atomic numbers, it gives us the number of atoms, upon the hypothesis, in equal bulks of the metals. In the following table the first column of figures expresses nearly the number of atoms in, and the second column of figures, the conducting power of, equal volumes of the metals named:—

Atoms.		Conducting Power.
1·00	gold	6·00
1·00	silver	4·66
1·12	lead	0·52
1·30	tin	1·00
2·20	platinum	1·04
2·27	zinc	1·80
2·87	copper	6·33
2·90	iron	1·00

So here iron, which contains the greatest number of atoms in a given bulk, is the worst conductor excepting one. Gold, which contains the fewest, is nearly the best conductor; not that these conditions are in inverse proportions, for copper, which contains nearly as many atoms as iron, conducts better still than gold, and with above six times the power of iron. Lead, which contains more atoms than gold, has only about one-twelfth of its conducting power; lead, which is much heavier than tin and much lighter than platina, has only half the conducting power of either of these metals. And all this happens amongst substances which we are bound to consider, at present, as elementary or simple. Whichever way we consider the particles of matter and the space between them, and examine the assumed constitution of matter by this table, the results are full of perplexity.

Now let us take the case of potassium, a compact metallic substance with excellent conducting powers, its oxide or hydrate a non-conductor; it will supply us with some facts having very important bearings on the assumed atomic construction of matter.

When potassium is oxidized, an atom of it combines with an

atom of oxygen to form an atom of potassa, and an atom of potassa combines with an atom of water, consisting of two atoms of oxygen and hydrogen, to form an atom of hydrate of potassa, so that an atom of hydrate of potassa contains four elementary atoms. The specific gravity of potassium is 0·865, and its atomic weight 40; the specific gravity of cast hydrate of potassa, in such state of purity as I could obtain it, I found to be nearly 2, its atomic weight 57. From these, which may be taken as facts, the following strange conclusions flow. A piece of potassium contains less potassium than an equal piece of the potash formed by it and oxygen. We may cast into potassium oxygen atom for atom, and then again both oxygen and hydrogen in a twofold number of atoms, and yet, with all these additions, the matter shall become less and less, until it is not two-thirds of its original volume. If a given bulk of potassium contains 45 atoms, the same bulk of hydrate of potassa contains 70 atoms nearly *of the metal potassium*, and besides that, 210 atoms more of oxygen and hydrogen. In dealing with assumptions, I must assume a little more for the sake of making any kind of statement; let me therefore assume that in the hydrate of potassa, the atoms are all of one size, and nearly touching each other, and that in a cubic inch of that substance there are 2800 elementary atoms of potassium, oxygen and hydrogen; take away 2100 atoms of oxygen and hydrogen, and the 700 atoms of potassium remaining will swell into more than a cubic inch and a half, and if we diminish the number until only those containable in a cubic inch remain, we shall have 430, or thereabout. So a space which can contain 2800 atoms, and amongst them 700 of potassium itself, is found to be entirely filled by 430 atoms of potassium as they exist in the ordinary state of that metal. Surely then, under the suppositions of the atomic theory, the atoms of potassium must be very far apart in the metal, *i. e.* there must be much more of space than of matter in that body: yet it is an excellent conductor,—and so space must be a conductor; but then what becomes of shell-lac, sulphur, and all the insulators? for space must also by the theory exist in them.

Again, the volume which will contain 430 atoms of potassium, and nothing else, whilst in the state of metal, will, when that potassium is converted into nitre, contain very nearly the same number of atoms of potassium, *i. e.* 416, and also then seven times as many, or 2912 atoms of nitrogen and oxygen besides. In carbonate of potassa the space which will contain only the 430 atoms of potassium as metal, being entirely filled by it, will, after the conversion, contain 256 atoms more of potassium, making 686 atoms of that metal, and, in addition, 2744 atoms of oxygen and carbon.

These and similar considerations might be extended through compounds of sodium and other bodies with results equally striking; and indeed still more so, when the relations of one substance, as oxygen or sulphur, with different bodies are brought into comparison.

I am not ignorant that the mind is most powerfully drawn by the phenomena of crystallization, chemistry and physics generally, to the acknowledgement of centres of force. I feel myself constrained, for the present hypothetically, to admit them, and cannot do without them; but I feel great difficulty in the conception of atoms of matter which in solids, fluids and vapours are supposed to be more or less apart from each other, with intervening space not occupied by atoms, and perceive great contradictions in the conclusions which flow from such a view.

If we must assume at all, as indeed in a branch of knowledge like the present, we can hardly help it, then the safest course appears to be to assume as little as possible, and in that respect the atoms of Boscovich appear to me to have a great advantage over the more usual notion. His atoms, if I understand aright, are mere centres of forces or powers, not particles of matter, in which the powers themselves reside. If, in the ordinary view of atoms, we call the particles of matter away from the powers, a, and the system of powers or forces in and around it, m, then, in Boscovich's theory, a, disappears, or is a mere mathematical point, whilst in the usual notion it is a little, unchangeable, impenetrable piece of matter, and m is an atmosphere of force grouped around it.

In many of the hyphotbetical uses made of atoms, as in crystallography, chemistry, magnetism, &c., this difference in the assumption makes little or no alteration in the results; but in other cases, as of electric conduction, the nature of light, the manner in which bodies combine to produce compounds, the effects of forces, as heat or electricity, upon matter, the difference will be very great.

Thus, referring back to potassium,—in which as a metal the atoms must, as we have seen, be, according to the usual view, very far apart from each other,—how can we for a moment imagine that its conducting property belongs to it, any otherwise than as a consequence of the properties of the space, or as I have called it above, the m? So also its other properties in regard to light or magnetism, or solidity, or hardness, or specific gravity, must belong to it, in consequence of the properties or forces of the m, not those of the a, which, without the forces, is conceived of as having no powers. But then surely the m is the *matter* of the potassium, for where is there the least ground (except in a gratuitous assumption) for imagining a difference in kind between the nature of that space, midway between the centres of two contiguous atoms, and any other spot between these centres? a difference in degree, or even in the nature of the power consistent with the law of continuity, I can admit, but the difference between a supposed little hard particle and the powers around it I cannot imagine.

To my mind, therefore, the a or nucleus vanishes, and the substance consists of the powers or m; and indeed what notion can we form of the nucleus independent of its powers? All our perception and knowledge of the atom, and even our fancy, is limited to ideas of its powers: what thought remains on which to hang the imagination of an a independent of the acknowledged forces? A mind just entering on the subject may consider it difficult to think of the powers of matter independent of a separate something to be called *the matter*, but it is certainly far more difficult, and indeed impossible, to think of or imagine that *matter* independent of the powers. Now the powers we know and recognise in every phenomena of the creation, the abstract matter in none; why then assume the existence of that of which we are ignorant, which we cannot conceive, and for which there is no philosophical necessity?

Before concluding these speculations I will refer to a few of the important differences between the assumption of atoms consisting merely of centres of force, like those of Boscovich, and that other assumption of molecules of something specially material, having powers attached in and around them.

With the latter atoms a mass of matter consists of atoms and intervening space, with the former atoms matter is everywhere present, and there is no intervening space unoccupied by it. In gases the atoms touch each other just as truly as in solids. In this respect the atoms of water touch each other whether that substance be in the form of ice, water, or steam; no mere intervening space is present. Doubtless the centres of force vary in their distance one from another, but that which is truly the matter of one atom touches the matter of its neighbours.

Hence matter will be *continuous* throughout, and in considering a mass of it we have not to suppose a distinction between its atoms and any intervening space. The powers around the centres give these centres the properties of atoms of matter; and these powers again, when many centres by their conjoint forces are grouped into a mass, give to every part of that mass the properties of matter. In such a view all the contradiction resulting from the consideration of electric insulation and conduction disappears.

The atoms may be conceived of as highly *elastic*, instead of being supposed excessively hard and unalterable in form; the mere compression of a bladder of air between the hands can alter their size a little; and the experiments of Cagniard de la Tour carry on this change in size, until the difference in bulk at one time and another may be made several hundred times. Such is also the case when a solid or a fluid body is converted into vapour.

With regard also to the *shape* of the atoms, and, according to the ordinary assumption, its definite and unalterable character, another view must now be taken of it. An atom by itself might be conceived of as spherical or spheroidal, or, where many were touching in all directions, the form might be thought of as a dodecahedron, for any one would be surrounded by and bear against twelve others on different sides. But if an atom be conceived to be a centre of power, that which is ordinarily referred to under the term *shape*, would now be referred to the disposition and relative intensity of the forces. The power arranged in and around a centre might be uniform in arrangement and intensity in every direction outwards from that centre,

and then a section of equal intensity of force through the radii would be a sphere ; or the law of decrease of force from the centre outwards might vary in different directions, and then the section of equal intensity might be an oblate or oblong spheroid, or have other forms ; or the forces might be disposed so as to make the atom polar ; or they might circulate around it equatorially or otherwise, after the manner of imagined magnetic atoms. In fact nothing can be supposed of the disposition of forces in or about a solid nucleus of matter, which cannot be equally conceived with respect to a centre.

In the view of matter now sustained as tho lesser assumption, matter and the atoms of matter would be mutually penetrable. As regards the mutual penetrability of matter, one would think that the facts respecting potassium and its compounds, already described, would be enough to prove that point to a mind which accepts a fact for a fact, and is not obstructed in its judgment by preconceived notions. With respect to the mutual penetrability of the atoms, it seems to me to present in many points of view a more beautiful, yet equally probable and philosophic idea of the constitution of bodies than the other hypotheses, especially in the case of chemical combination. If we suppose an atom of oxygen and an atom of potassium about to combine and produce potash, the hypothesis of solid unchangeable impenetrable atoms places these two particles side by side in a position easily, because mechanically, imagined, and not unfrequently represented ; but if these two atoms be centres of power they will mutually penetrate to the very centres, thus forming one atom or molecule with powers, either uniformly around it, or arranged as the resultant of the powers of the two constituent atoms ; and the manner in which two or many centres of force may in this way combine, and afterwards, under the dominion of stronger forces, separate again, may in some degree be illustrated by the beautiful case of the conjunction of two sea waves of different velocities into one, their perfect union for a time, and final separation into the constituent waves, considered, I think, at the meeting of the British Association at Liverpool. It does not of course follow, from this view, that the centres shall always coincide ; that will depend upon the relative disposition of the powers of each atom.

The view now stated of the constitution of matter would seem to involve necessarily the conclusion that matter fills all space, or, at least, all space to which gravitation extends (including the sun and its system); for gravitation is a property of matter dependent on a certain force, and it is this force which constitutes the matter. In that view matter is not merely mutually penetrable, but each atom extends, so to say, throughout the whole of the solar system, yet always retaining its own centre of force. This, at first sight, seems to fall in very harmoniously with Mossotti's mathematical investigations and reference of the phenomena of electricity, cohesion, gravitation, &c., to one force in matter ; and also again with the old adage, "matter cannot act where it is not." But it is no part of my intention to enter into such considerations as these, or what the bearings of this hypothesis would be on the theory of light and the supposed ether. My desire has been rather to bring certain facts from electrical conduction and chemical combination to bear strongly upon our views regarding the nature of atoms and matter, and so to assist in distinguishing in natural philosophy our real knowledge, *i. e.* the knowledge of facts and laws, from that, which, though it has the form of knowledge, may, from its including so much that is mere assumption, be the very reverse.

SOLUBILITY OF THE METALS IN PERSULPHATE AND PERCHLORIDE.

By James Napier, Mem. Ch. S. I.

Having been informed of the great quantity of water impregnated with copper, which is constantly issuing from the Pary's Mines, Anglesea, and of the great expense of obtaining the copper in a metallic state, I thought it very probable that the metal might be more economically extracted by means of a galvanic current, or what is known as the electrotype process. For the purpose of making the necessary experiments to determine whether or not the opinion which I entertained was correct, I procured a quantity of the water. I was also favoured at the same time with the details of the present mode of extracting the metal, and of the extent of the manufacture. By these details it appears that the average quantity of water which yearly issues from the mines amounts to 700 millions of gallons. For the purpose of obtaining the copper, the water is collected in pits, into which are put scraps of old iron, iron turnings and the like, upon which the copper precipitates.

The average product of copper is from 55 to 60 tons, and the iron consumed in obtaining it is 600 tons. The copper found in these waters, as indicated from the precipitate obtained, varies from four to thirty per cent., according to the wetness of the season ; the sample, upon which my experiments were performed, was collected during the dry season, and was consequently rich in copper ; its specific gravity was 1·055 at 60° F. The solid contents of one gallon weighed 4960 grains, which gave peroxide of iron 1680 grains, oxide of copper 80 grains, sulphuric acid 3040 grains, muriatic acid 38 grains, and 122 grains of earthy matters, which were not examined. The iron existed in the water as the persulphate.

My first analytic operation was one I had found to answer in analyzing copper ores, namely, wrapping a strip of brown paper round a piece of iron, attaching this to a piece of copper, and immersing both in a solution of the copper ore in muriatic acid ; but I found that the first action which took place was the complete reduction of the persalt of iron to the state of protosalt, at the expense of the copper pole : after which the electric current began to effect its object, the copper being deposited, but from the copper which had been dissolved having also to be deposited, the consumption of iron was 658 grains, while the actual increase in the weight of the copper pole was only 64 grains, the quantity of copper originally held in solution. The reaction which took place may be expressed as follows :—

1680 grains of peroxide of iron composed of	iron	582·7	protosulphate of iron.
	iron	582·7	
	oxygen	171·5	
	oxygen	171·5	
	oxygen	171·5	
2568 grains of sulphuric acid.	acid	856·0	
	acid	856·0	
	acid	856·0	sulphate of copper.
Copper pole.	copper	690.7	

giving 690·7 grs. + 64 grs. to be deposited by the electric current.

Different arrangements of batteries were tried ; platinum, silver and lead were also substituted for the copper, but in no case was a deposit obtained from the water until the iron was first brought into the state of a protosalt ; but when this was effected, I obtained by the method first described 63 grains of copper by the loss of 58 grains of iron.

During these experiments I found that silver, tin, lead, antimony, bismuth, cobalt, nickel, and several other metals were very soluble in neutral persalts of iron, reducing it to the state of a protosalt. In order to repeat these experiments, I prepared some perchloride of iron in the following manner, adding to the boiling solution of the sulphate as much nitric acid as was necessary to peroxidize the iron, then precipitating by ammonia, washing this well with hot water, and dissolving with hydrochloric acid, evaporating nearly to dryness, and adding a quantity of distilled water. The persulphate used was obtained as a dry white powder ; both salts were neutral.

I was aware that Professor Fuchs had recommended the boiling of a piece of clean copper in perchloride of iron, as a means of ascertaining the quantity of iron in an ore of that metal, and also to ascertain the amount of copper in certain copper ores. For iron ores I have found great difficulty in obtaining uniform results, from the great difficulty of knowing the exact period at which the iron is all reduced to the proto state, for the copper put in continues to dissolve until the chloride is all converted into a subchloride ; this result is effected, however, much more rapidly when the iron salt is neutral than when it contains free acid, a condition specially recommended by Fuchs.

The most uniform results are obtained by allowing the copper to remain until the solution becomes colourless ; on diluting with cold water, the whole of the copper is precipitated as a white powder ; the clear solution, if the process is completed, will contain no copper, and there will be two equivalents of copper dissolved from the metal for every equivalent of peroxide of iron

formerly in the solution. It occasionally happens, however, when neutral salts of iron are used, that the copper becomes encrusted with a white deposit, upon which crystals of the subchloride of copper collect, and thus protect it from further action; this is prevented by boiling, or taking out the copper, removing the crust, washing it, and putting it into the solution again, when the action goes on as before. When the persulphate of iron is used for this purpose instead of perchloride no subsalt is formed, and the result is uniform, one equivalent of copper being dissolved for every equivalent of peroxide of iron present in the solution.

I may mention one especial application of the solubility of copper in perchloride of iron, namely, the dissolving of copper from the surface of silver, such as copper that has been used as a mould in which silver has been deposited; when this solution becomes saturated with copper, a little ammonia added precipitates the iron as a peroxide and combines with the copper, forming a soluble double chloride, which may be immediately separated by filtration and the precipitate washed; the peroxide of iron again dissolved in hydrochloric acid is fitted for a renewal of the same process.

I may here mention, that if, previous to adding the ammonia, there be a little perchloride of iron put into the mixture of subchloride of copper and protochloride of iron, an immediate change is effected, the colour of the solution becomes green, and on adding ammonia to this, both copper and iron are precipitated.

Persulphate of iron cannot be used for the purpose of dissolving copper from silver, on account of the easy solubility of silver in solutions of this salt, and the peculiar destructive action which it has upon alloyed silver. The tenacity of standard silver is completely destroyed by it. I have used thin sheets, weighing from 60 to 70 grains, and when only four grains were apparently dissolved, the remainder had been so much affected that it crumbled between the fingers like a dried leaf.

When silver is put into a solution of persulphate of iron an immediate action takes place, a yellowish cloud begins to form in the solution; if heated the action is much more rapid, a yellow oxide of iron forming upon the sides of the vessel, and there is also a brown precipitate deposited; the iron in the solution is converted into the proto state, shining particles of metallic silver float through the solution, and sulphate of silver crystallizes on the vessel, but in no case did I find an equivalent of silver for the equivalent of peroxide of iron; by slow evaporation the solution yielded crystals of protosulphate of iron and sulphate of silver.

Tin is very readily dissolved both in the persulphate and perchloride of iron, and completely reduces the iron to the proto state. When the solution is cold, the solution is effected in about an hour; when hot, in a few minutes; the iron is reduced to the proto state when only half an equivalent of tin is dissolved for every equivalent of peroxide. My first impression was, that the first atoms of protosalt of tin formed, reduced a corresponding atom of peroxide of iron, and was converted into a persalt; but saturating with ammonia, and adding it in great excess, the precipitated oxide of tin was not redissolved, and had every other character of a protosalt. Whether this was owing to the formation of *a bisulphate or bichloride of tin*, I did not ascertain. By boiling or long standing, there is an equivalent of tin dissolved for every atom of perchloride of iron, but I did not obtain the same result in the persulphate.

Cadmium is very soluble in persalts of iron; in the persulphate an equivalent of cadmium is dissolved for the equivalent of persulphate of iron; but in perchloride of iron two equivalents of cadmium are dissolved for every equivalent of perchloride of iron, forming, as in the case of copper, a subchloride, which was not precipitated by the addition of water.

Lead is also dissolved in persalts of iron, reducing a portion of the iron to the state of a proto salt; the lead becomes covered with a thin crust of sulphate or chloride, which seems to protect it from further action; when the iron solution is boiled with the lead much more is dissolved, and a precipitate of peroxide of iron collects at the bottom. This action of iron on lead may account for the rapid destruction of leaden tanks, noticed by Mr. West at a former meeting of the British Association: when spring water, which had been running into a lead tank for many years without the slightest action upon the lead, was conveyed through iron pipes to the tanks, the tanks were destroyed in six years.

Antimony is not very soluble in persulphate of iron even when heated, but it is very soluble in perchloride of iron when hot, reducing the iron to a protochloride in a short time, the solution becoming of a light-brownish colour. I found that if kept boiling slowly for a long time the antimony loses an equivalent of metal for every equivalent of peroxide of iron, giving us the idea of the existence of a compound of antimony with chlorine of one to one. This solution was not examined further than by dilution with water, which precipitated almost all the antimony as a white powder, undergoing the usual changes of common chloride, except when the dried precipitate was boiled in nitric acid, in which it dissolved with the evolution of nitrous gas.

Arsenic is very soluble in perchloride of iron, reducing the iron to the state of protochloride, losing also with long boiling an equivalent of metal for every equivalent of peroxide of iron in the solution; but this result is not obtained without long boiling.

Bismuth is very soluble in perchloride of iron, slightly in persulphate; the perchloride is completely reduced to the state of protochloride, a full equivalent of metal being dissolved for the peroxide of iron present; this is wholly precipitated by dilution.

Cobalt is very soluble in perchloride of iron, reducing it completely, changing the solution to a pink colour. The cobalt salt formed crystallizes from this solution very easily.

Nickel is also soluble in perchloride of iron, giving a precipitate of brown oxide of iron; the solution becomes green, containing protochloride of iron and nickel; a portion of the nickel is precipitated as a fine white powder by dilution.

Platinum in persulphate and perchloride of iron produced no change, and lost nothing in weight.

Gold boiled for a long time in perchloride of iron in two experiments lost 0·2 and 0·3 of a grain. In both these instances beautiful crimson-red crystals, in perfect octahedrons, were obtained, adhering to the metal and also to the containing vessel. I did not try whether they contained any gold. These results were only obtained twice in six different trials; they were procured with iron prepared at different times. Platinum was always tried at the same time with the gold, and when there was no gold dissolved I never obtained any crystals.

I need hardly mention that both zinc and iron, when put into the persalts of iron, first reduce the persalt to the protosalt, which fully accounts for the great consumption of iron for the small quantity of copper obtained in these waste waters of mines, and not, as was generally supposed, from the existence of free acid; the copper is never all precipitated from the water so long as persalts of iron exist in the solution. The presence of persalts of iron also prevents the deposition of the copper by a galvanic current; but the proportionate quantity of persalts of iron necessary to resist completely the deposition of copper was not ascertained.

In no one case did I find any double salt formed between the iron and metal dissolved in it, but when the solution containing them was evaporated the salts of the two metals crystallized separately.

In all cases where the process is conducted cold, the solution of the metal takes place at the bottom of the vessel and progresses upwards; this is beautifully exhibited when a tall glass is used with a solution of perchloride of iron, and a slip of copper reaching to the bottom; the solution first becomes green at the lower part, and this advances slowly upwards till it reaches the top, but before the change of colour reaches the top the bottom has become colourless from the formation of subchloride.

THE EQUILIBRIUM OF FRAMEWORK.

ARTICLE I.

An important department in all structures composed of parts, is the framework. In this, the judgment and ingenuity of the engineer and architect are frequently displayed to more advantage than in any other portion of the work. The converse is likewise not uncommon; and a fault in this department, introduced by inaccurate conceptions of the conditions to be fulfilled, not unfrequently mars the stability of the whole structure, even when, in other respects, the arrangement is faultless in design and execution.

We conceive it, therefore, to be of importance to indicate the principles which ought to govern the arrangement of every system

of frame-work; and bearing in mind that, if we except the difference of material which implies a practical difference in the *mode* of construction, the law of equilibrium, like every other physical law, is universal in its application, and may with facility be translated from one species of structure to another of the same class.

The first point to be determined, when a structure is to be erected, is the general contour; the next is to contrive a disposition of parts which shall insure the stability of the whole, under the given amount of *stress* with the least amount of material. The former depends upon the nature of the structure, and the purpose for which it is designed; the latter is resolved by a knowledge of the nature and properties of the material employed, and a correct estimate of the direction and amount of the various pressures which require to be counteracted.

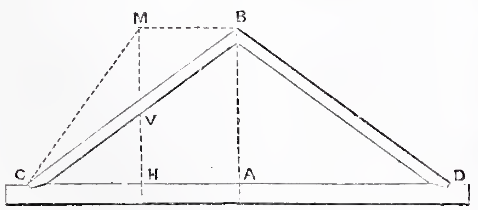
It is to this last that we intend, in the meantime, to confine our attention; and the condition which it comprehends is shortly this, that a disposition of parts be made of such a nature, that any pressure tending to produce change of form in one direction, that is disrupture of the structure, shall be counteracted and neutralized by some other part. This effect, as we shall presently see may be produced in the simplest manner by combining the pieces employed to preserve stability of the frame-work, so that they may form a series of triangular figures; because then no change can take place without the pieces forming the sides of these figures becoming longer by extension or shorter by compression. It is for this reason that, when the main pieces of a frame form quadrilateral figures, other pieces are placed in the direction of the diagonals of the quadrilaterals: such pieces are termed *braces*,—a name which is common to all those parts introduced into frame-work for the purpose of preventing flexure in the other parts; and an arrangement of braces of the character referred to is termed *diagonal bracing*, and is commonly used in frame-work requiring great strength and stiffness. The pieces in a system which resist a compressing force are usually termed *struts;* those made fast at both ends to resist a force of extension are, in the same technical phraseology, denominated *ties*.

These parts and their offices are all exemplified in roofing. Usually we find the roof supplied by a *roof-truss*, consisting of two rafters sloping from the *roof-tree* to the *wall-plate*, and connected at bottom by a horizontal *tie-beam*. This simple case we select as a first example of the mode of determining the conditions of equilibrium of a frame composed of longitudinal pieces disposed triangularly. For distinctness, let us put the question in the following form :—

I. Let there be a simple roof-truss consisting of equal rafters and a tie-beam, supporting a given load uniformly distributed among the rafters: to determine the tension upon the tie-beam.

Here the pressures which the rafters sustain at the vertex B

Fig. 1.



are equal, because the load upon each is equal; and the rafters being in the meantime supposed inflexible, and fixed at their lower extremities to the tie-beam, the pressures must be exerted horizontally. Under these circumstances the load of each rafter may be supposed to be attached at its middle point, and to act in the vertical line M H; and this force being decomposed will be represented by the forces V C and C H. The whole force, then, upon C, is equivalent to a vertical force equal to the weight, and a horizontal force $\text{H C} = \text{M B}$.

If, therefore, we represent the whole weight of the rafter and load by W, and the horizontal force which it exercises at C by H, then we shall have

$$\frac{\text{W}}{\text{H}} = \frac{\text{V H}}{\text{H C}} = \frac{2\,\text{V H}}{\text{H C}} = 2 \tan \text{B C A}.$$

And from this we readily find that

$$\text{H} = \tfrac{1}{2}\,\text{W} \cot \text{B C A} = \tfrac{1}{2}\,\text{W} \frac{\text{A C}}{\text{B A}}$$

which of course also expresses the horizontal pressure at D.

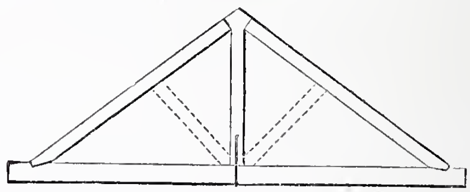
From this it is manifest that the tension of the tie-beam will increase as the length of the rafters decrease, the span remaining the same. Again, if we inquire into the condition of pressure upon the feet of the rafters, we find by a little investigation, that M C will attain a minimum value when $\tan \text{B C A} = \frac{1}{\sqrt{2}}$ that is, when the angle of inclination B C A to the horizon is 35° 16′. It is, therefore, at this inclination of the roof of a given span, whose trusses are of the simple form shown by the dark lines of the diagram, that the least pressure will be produced upon the feet of the rafters; and the same must obviously apply to any truss of frame-work, under similar conditions.

The following practical and useful expression is likewise readily deduced; that is, calling w the weight per square foot of a roof; $2\,s$ the span, a the angle of the rafters to the plane of the horizon, d the distance between each two principal rafters, then if T be taken to represent the thrust in the direction of the rafters, we have

$$\text{T} = \frac{w\,s\,d}{2 \sin a \cos a} = \frac{w\,s\,d}{\sin 2\,a}.$$

It must be observed that in the preceding discussion, we have considered the parts as perfectly rigid material, and the tie-beam without weight; were this strictly true, then the simple form of truss shown by the diagram, might be used for spars much greater than the practical conditions of weight and flexibility in the tie-beam admit. Under these conditions, if the tie-beam be supported only at its two ends C and D, it will hang down or *sag* in the middle at A; and by that means its strength is diminished. To prevent this result, the middle of the tie-beam is suspended from the ridge by a *king-post*, B A, as shown in fig. 2.

Fig. 2.

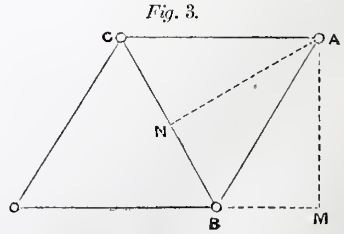


The strain upon this tie might be shown by another process of inquiry to be equivalent to *five-eighths* of the weight of the tie-beam. At first sight it might appear that the tension upon the king-post would depend upon the modulus of elasticity of the tie-beams, that is upon the amount of flexure which a given force upon it would produce, and that the determination would therefore depend upon the kind of material; but, as every species of material is in some degree flexible, it is plain that the king-post, in order to prevent *all* yield, will be required to resist the same amount of strain for the same weight of beam, whatever the degree of flexibility may be.

Again, the rafters will also *sag* in consequence of their flexibility; and, to prevent this, they have frequently their intermediate points supported by braces shown dotted in fig. 2.

II. A quadrilateral frame has one of its angles stiffened by a brace, and the frame tends to rack* by a given force: to find the strain upon the brace.

Fig. 3.



Let the frame tend to rack at A by two opposite and equal forces W and W′,

* When a frame alters its position by changing the amount of its angles, it is said to rack.

the one acting in A C, and the other at B parallel to C A. The force W tends to turn the piece A B round A, and this tendency is resisted by the brace B C. But to fulfil this condition, it is plain that the moments of the forces about A as a centre, must be equal, for otherwise the system would not be in equilibrio, which is contrary to the assumption; if R therefore denote the resistance offered to flexure by the brace, and AN be the perpendicular to the direction of the resisting force R, and AM be the perpendicular to the racking force W, there is

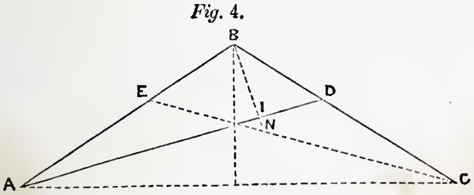
$$R \times AN = W \times AM,$$

that is, the moment of the resisting force of the brace about the angle which it stiffens, is equal to the moment of the racking force; and this is the case, whether the brace act as a strut, or as a tie.

In the same manner, it might be shown that if several angles be braced, the sum of the moments of the resisting force of each brace about the angle which it stiffens, is equal to the whole moment of the racking force which acts upon the frame. And, knowing this, the necessary strength of bracing force may be determined in practice.

To take a particular case, let A B C be a roof braced by an

Fig. 4.



oblique tie A D. The frame may be considered as a frame urged to rack about A, and preserved by the brace A D. The forces which urge the frame to rack, are the whole weight of the roof acting downwards, and the supporting pressures acting upwards. If the whole weight of the roof be represented by W, and if the frame be isosceles, a weight $= \frac{1}{2}$ W will be supported on each of the walls A and C, these being supposed horizontal; and the moment of force tending to rack the frame, is therefore $\frac{1}{2} W \times \frac{1}{2} AC$. This, on the assumption that the structure is stable, is equal to the moment of the force of the brace A D, round B, supposing this to be the only brace in the system; hence drawing B N perpendicular on A D, we have

$$\text{force on tie } AD = \tfrac{1}{4} W \frac{AC}{BN}$$

And if there be other ties as C E, then the sum of their moments round A, will be equal to the moment which tends to rack the frame.

III. A horizontal piece, B C, is loaded and fixed at one end B, and supported beneath by an oblique strut, A D, which rests against a fixed point A; to determine the condition of equilibrium. (fig. 5).

Let the weight W, suspended from the extremity C of the beam, denote the load; then, if we denote the distance B D by l, and the distance D C, by l', and put a for the angle which the strut makes with the vertical line; and further, suppose that the frame is free to turn about the points A and B, it will readily appear that the tendency of the weight at the point C, is to produce an upward pressure at the point B, which will be represented by $W . \frac{l'}{l}$. The point D will, therefore, have to bear a pressure equal to this added to W, that is, a pressure in amount, represented by $W . \frac{l+l'}{l}$. And as the pressure on the point D is borne by the strut, the total pressure in the direction of A D will be represented by

$$W . \frac{l+l'}{l \cos a}$$

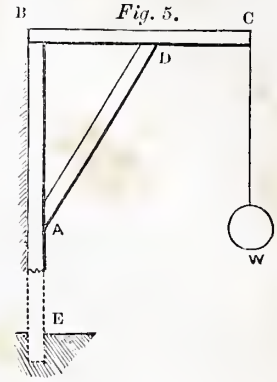
At the same time, there will arise from this pressure at D, a tension on the part B D, represented by

$$W . \frac{l+l'}{l} . \tan a.$$

In order, then, that the parts B C and A D may be sufficiently strong to maintain themselves in equilibrium, the strut A D must resist the pressure represented by the first of these expressions, and the part B O, an effort which is due in part to the tension on B D, represented by our last expression, and to the action of the weight W, on the part D C, which tends to bend that part. Hence, by taking into account the depth d, and the breadth b, of the beam, according to the usual formula, we have, as the limit of effort, on a superficial unit of the transverse section of D C, when the section is rectangular,

$$\frac{W}{b\,d^2}\left(\frac{d\,(l+l')\tan a}{l} + l'\right)$$

Fig. 5.



If the horizontal piece B C be fixed at B, to an upright B E, made fast at E, then the upright from A to E will be compressed by the entire weight W, while the part B A will be placed under tension by a pressure represented by $W\frac{l'}{l}$. The part A E, is therefore in a state of compression arising from the weight W acting at a distance $l + l'$ from the axis; consequently, the limit of its resistance on a unit of surface, the beam being rectangular, is expressed by

$$\frac{W}{b\,d^2}\,(6\,(l+l') + d).$$

And the same limit for the part B A which is extended by the force $W\frac{l'}{l}$ acting at the same distance will be represented by

$$\frac{W}{b\,d^2}\left(6\,(l+l') + d\frac{l'}{l}\right).$$

The vertical pressures in these cases are then at B upwards, and at A downwards, and their difference is the weight W. But pressures are not here necessarily determined by the form of the frame; the whole may be supported at A, or the whole at B, or the weight may be divided between the points of support in any proportion.

THE CAUSES AND MEANS OF PREVENTING SALINE FLORESCENCE ON WALLS.

THE mineral substances chiefly used in building, consist of lime, sand, and different kinds of stone, neither of which contain any saline or deliquescent matter as an integral part of their composition. No trace of salt or alkali is mentioned in the analyses of various stones that were examined with reference to the selection for building the New Houses of Parliament. Bricks are made of clay, which consists principally of alumina and silica, but generally containing some portion of lime, in the state of carbonate or sulphate; carbonate of magnesia; iron in the state of oxide, or combined with sulphur, and common culinary salt; these various materials, when exposed to a red heat, act chemically on each other; the magnesia most probably will combine with the sulphuric acid, which it obtains partly from the iron pyrites mixed with the clay, and partly from the fuel, if coal is used. It is this sulphate of magnesia (common Epsom salts) which is occasionally found to cover the surfaces of newly-built walls with an efflorescence like hoar-frost.

The presence of saline or deliquescent matter on the surface of a building, either internally or externally, may, to a certain extent, be attributed to carelessness, ignorance, or inattention of those who superintend the construction of an edifice. Salts, alkalies, or acids, according to the usual acceptation of such terms, do not necessarily form any part whatever of building materials. Nearly all animal and vegetable substances, when in a state of putrefaction or decay, produce a certain quantity of saline or alkaline matter, which absorbs moisture rapidly; therefore, every precaution should be taken to

avoid admitting such substances into a building where damp walls are likely to be of serious importance. It has long been a practice among builders to "parget" all the flues in a building: for this purpose, cartloads of excrement, frequently of many kinds, are procured from a cow-shed, and mixed with a little mortar, to put a coating throughout the interior of the chimneys. Another objectionable practice is common during the time that the carcasses of a building is progressing, and partially until the "finishing" is nearly completed, which is that of allowing workmen to urinate indiscriminately against the angles and recesses of the interior of a new building: no part is more frequently selected than the fire-places, before the stoves are placed therein; and in an extensive building, where hundreds of workmen are employed during several years, the quantity must be quite sufficient to saturate certain parts of the structure beyond all remedy. Both these causes undoubtedly increase the presence of salts, &c., on such parts of the interior of buildings as are elevated above the influence of the ground. To show that dung and urine have long been considered to yield saltpetre abundantly, a proclamation of Charles I., in 1625, ordered all persons to save the urine of their families, and as much as they could of that of their cattle, to supply saltpetre for the manufacture of gunpowder; and in 1627, the saltpetre-makers were authorised to take away the ground of all dove-houses, stables, lairs, or other places where cattle were kept. There are many other sources by which salts are conveyed into or communicated to the walls of a building, but those already mentioned appear to be the most copious, and which may be considerably decreased.

Under ordinary circumstances, it is scarcely possible to get rid of the various saline or deliquescent substances that have once been admitted into the walls of a building. The fixed alkalis (potash and soda) may probably be considered imperishable; no length of time can injure them; they may effloresce, or, more properly, they may crystallize on the surface of a wall, and totally or partially disappear again and again, as often as a change in temperature, or of dryness, or humidity, takes place: these changes may be daily, or the salts may remain inactive during ages; and from some favourable cause, a crop of crystals may be produced as flourishingly as if the wall had been recently erected. The only way to abate the evil is to brush off the crystals, dry, whenever they appear in the most flourishing condition. If potash has been introduced into the walls, either from the putrefaction of animal or vegetable substances, such as has been named, or from other sources, however thick the wall may be, it will make its way to the surface, and then absorbing nitrogen from the atmosphere, which contains 70 or 80 per cent. of it, nitrate of potash (or saltpetre) is produced.

If we imagine the possibility of salts in a crystalline state getting to the interior of a dry wall, beyond the influence either of moisture or considerable variation of temperature, in such case they would unquestionably remain crystallized as they were deposited; but such a state of things is never likely to take place: salts are generally communicated to a building in weak solutions; the water very gradually evaporates, carrying with it, from the interior of the wall, the molecules which compose salt. The solution having arrived at the surface, so as to be freely in contact with the atmosphere (which is always essential to crystallization), evaporation continues until the solution is sufficiently strong to crystallize, leaving only the mother water in the wall, which is indicated by a certain dampness.

Lime, mortar, or some other sort of calcareous earth, seems to act as a vivifying principle, to set the molecules of salt and water in action; if no lime were present, crystallization would certainly be much less active. An increase of temperature, or a humid atmosphere, will slowly dissolve the salts; if both these causes occur at the same time, liquefaction will be rapid, and the newly-formed fluid will be absorbed into the wall as fast as the salts are dissolved. These changes will take place with every variation of atmosphere; a cool dry air, in a state of absolute rest or stagnation, is favourable to crystallization; a warm one, charged with aqueous vapour, will facilitate solution. It is extremely probable that several kinds of salts may be formed on the same wall, with their crystals intermixed, so as to escape the discrimination of a casual observer, and that each will crystallize and liquefy at different times, according to the temperature and the quantity of moisture in the atmosphere; should this be the case, perhaps the wall may never appear perfectly free from efflorescence, so long as the various stimulants of air, moisture, light, heat, and other causes of attraction, are in activity; and, since all attraction is mutual, it may readily be understood, that as the particles of water attract those of the alkaline salt, and retain them in solution, so the particles of alkaline salt will attract those of the water, and hold them in crystallization.

It is difficult to state with precision the relative power of different bodies to attract moisture from the atmosphere; that such power exists independently of temperature is scarcely probable, as thermal influence appears generally diffused over the face of nature. Some substances are more susceptible of sudden changes of temperature than others, and thereby may occasion a rapid precipitation of vapour, from the aerial or invisible state in which it exists in a warm atmosphere, to the fluid form on the surface of cold bodies: this circumstance arises solely from the solid mass of the wall requiring a much longer time to attain the same elevated temperature as the atmosphere. Bodies in contact with each other in due time arrive at one common temperature, by the hotter communicating the requisite proportion of the excess of its heat to the colder: the velocity of this communication varies in different bodies, some being quickly heated, and as quickly cooled; others undergoing these changes much more slowly. It is probable that the atoms or completely solid parts of all simple substances have exactly the same capacities for heat, and that the perfect or imperfect conducting power of substances will be proportioned to their porosity, sponginess, or the quantity of vacant space contained in their interstices. Dense bodies are generally the best conductors of heat; those which are most porous, conduct it very imperfectly; the metals, which are substances of the greatest density, transmit heat most rapidly; stones and earthy substances conduct it more slowly; wood is a bad conductor; and the natural clothing of animals—fur, hair, feathers, &c., are inferior to every other material in their power of communicating heat. These remarks are applicable only to the conducting power of solid substances: liquids are all very bad conductors of heat; therefore, independently of evaporation, a cold damp wall will continue at a low temperature much longer than a cold dry one; and hence it will influence the condensation of vapours during a greater length of time than if it were dry.

Various circumstances seem to infer the probability, that voltaic electricity, considered as a chemical agent, may act some part in conveying moisture from the atmosphere to the walls of a building. All substances naturally possess electrical energies, which are inherent in them; probably there may not be two substances, or even two distinct surfaces of the same substance, that are not in different electrical relations to each other; and it is a law of electricity, that bodies in opposite states attract each other. Lime, sand, bricks, and hair materials, with which walls are usually constructed and plastered, are all, when dry, bad conductors; whereas water is a good conductor of electricity; and whenever the atmosphere, or water, or any part of the surface of a body, gains accumulated electricity of a different kind from the contiguous substances, there is an immediate tendency to bring the parts into contact. In this manner, other circumstances being favourable, floating aqueous vapours may perhaps be imparted to a wall, and absorbed into it by capillary attraction.

Electric influence, as connected with the preceding inquiry, is merely offered as a HINT, with the view of inducing scientific men to investigate the subject. Hitherto the public are not in possession of any facts which have immediate reference to this important object.

CROSS'S HAND-LEVER GAUGE.

The hand-lever gauge is intended to indicate the slight variation that may take pace on metal plates from the 8th to the 500th part of an inch of thickness. The drawings are from one I have lately constructed, the same size, and have found it a very neat and useful instrument; and I think it calculated to be of great utility in many of our engineering shops.

Description of the drawings.—Fig. 1 shows the upper surface of the instrument; A A is a brass plate about one-eighth of an inch thick, and it is graduated at the broad extremity, and fitted into the ebony handle, E; B B is the index or indicator working on its pivot at *c*, with the short end bent at a right angle through the slot, D. Fig. 2 shows the instrument edgeways; F is the support to upper end of the indicator pivot, B, not shown in fig. 1, the lower end working in the plate; *h h* is a quadrant lever working on a small collar screw, I, which screws into the stud, *c*. The lever, E E, works on an axle in the stud, J, which is attached to the brass plate at s in fig. 1. The short end of the lever, E E, comes in contact with the point, K, and the other end with the quadrant lever; the stud, N, is to prevent the lever shifting out of its proper position when acted upon.

To use the instrument.—It must be held in the right hand with the index uppermost, so that the forefinger may press upon the long end of the lever, E E, and cause the quadrant lever to

act upon the short end of the indicator, which moves to the right as the points at K open. When the plate is inserted between them, the finger is removed; then by the circular spring, L L, acting in opposition to the quadrant lever, it takes back the in-

Fig. 1.

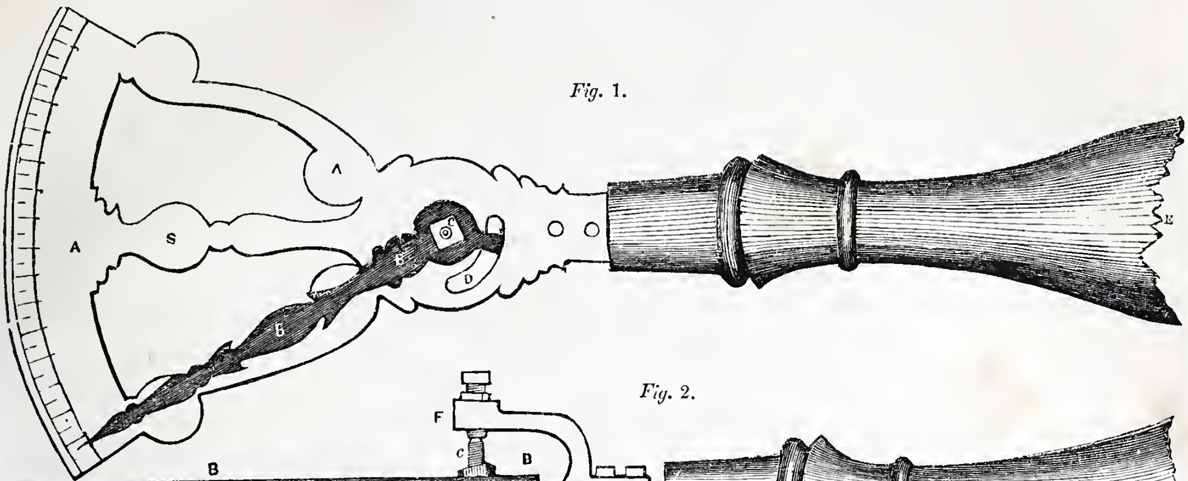
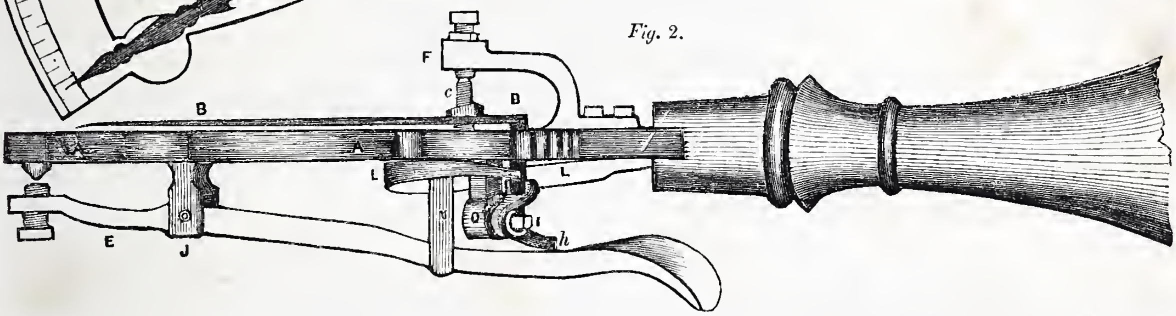


Fig. 2.



dicator, and denotes the thickness of the plate upon the graduated arc.

All the working parts should be made of steel, and hardened to prevent them from wearing.

MORIN'S EXPERIMENTS ON FRICTION.

We are indebted for the following very excellent summary of these admirably conducted investigations, to Professor Moseley's Illustrations of Mechanics. We may, at some future opportunity, add a description of the apparatus employed by M. Morin; but, in the meantime, it is only necessary to observe, that the results given in the following summary may be received with all that confidence which it is possible to extend to experiments which we do not see actually performed.

These experiments—into the mechanical details of which more precautions were introduced, and in which greater mechanical accuracy was probably attained, than in any which have preceded them—have placed the question of friction entirely in a new and a far more satisfactory position than it has before occupied. They were made at the expense of the French government, under the most favourable circumstances, by methods which have been fully and clearly detailed; and however opposed they may be in their results to all former experiments, and especially to those of Coulomb, it is impossible not to yield to them the greatest confidence.

The principal conclusions drawn from these experiments may be stated as follows:—They show the friction of two surfaces which have been for *a considerable time in contact*, to be not only different in its *amount*, but in its *nature*, from the friction of surfaces in *continuous motion*, especially in this, that this friction of quiescence is subject to causes of variation and uncertainty, from which the friction of motion is exempt. This variation does not appear to depend upon the *extent* of the surfaces of contact; for, with different pressures, the ratio of the friction to the pressure, or the co-efficient of friction, as it is called, varied greatly, although the surfaces of contact were the same.* The uncertainty which would have been introduced into every question of practical mechanics, and especially of construction, by this consideration, is, however, removed by a second very important fact developed accidentally in the course of the experiments. It is this, that by the slightest *jar* or *shock*, the most imperceptible *movement* of the surfaces of contact, their friction is made to pass from this state accompanying *quiescence* into that entirely different state of friction which accompanies *motion;* and as every machine or structure of whatever kind may be considered to be subject to such shocks or imperceptible motions of its surfaces of contact, it is evident that the state of friction to be made the basis on which all questions of statics are to be determined, should be that last mentioned, which accompanies continuous motion. Now the LAWS of this friction, thus accompanying motion, are shown by the experiments of M. Morin to be of remarkable *uniformity* and *precision*, and that under an extensive range of variation, as well in the *pressures* by which the surfaces are held in contact, as in the *dimensions* of those surfaces. They are these:—

1. The friction accompanying the motion of two surfaces between which no unguent is interposed, bears the same proportion to the force by which these surfaces are pressed together, whatever may be the amount of that force.

2. This friction is independent of the *extent* of the surfaces of contact.

3. Where unguents are interposed, a distinction is to be made between the case in which the surfaces are simply *unctuous* and *in intimate contact* with one another, and the case in which the surfaces are wholly *separated* from one another by an *interposed stratum of the unguent.* If the pressure upon a surface of contact of given dimensions be increased beyond a certain limit, the latter of these cases passes into the first; the stratum of unguent being *pressed out*, and the unctuous surfaces which it separated from one another being brought into intimate contact. As long as either of these two states remains, the laws of its friction are not affected by the presence of the unguent; but in the transition from the one state to the other, an exception is made to the independence of the friction upon the extent of the surface of contact; for supposing the extent of two surfaces of contact, between which a stratum of unguent is interposed, and sustaining a given pressure, to be continually *diminished*, it is evident that the portions of this pressure, which take effect upon each element of the surfaces of contact, will be continually increased, and that they may thus be so increased as to press out the interposed stratum of unguent, and cause the state of the surfaces to pass into that which we have designated as *unctuous*, thereby changing the co-efficient of friction.

It will be understood, from what has above been said, that there are three states, in respect to friction, into which the surfaces of bodies in contact may be made successively to pass: *one*, a state in which no unguent is present; the *second*, a state in which the surfaces are unctuous, but intimately in contact; the *third*, a state in which the surfaces are separated by an

* Thus, for instance, in the case of oak upon oak with parallel fibres, the co-efficient of friction of quiescence varied under different pressures, but upon the same surface, from ·55 to ·76.

entire stratum of the interposed unguent. Throughout each of these states the co-efficient of friction is the same; but it is essentially different in the different states, as will be seen from the following tables.

4. It is a law common to the friction of all the states of contact of two surfaces, that their friction, when in motion, is altogether independent of the *velocity* of the motion. M. Morin has verified this law, as well in various states of contact without interposed fluids, as in cases where water, oils, grease, glutinous liquids, syrups, pitch, &c., were interposed in a continuous stratum.

The variety of the circumstances under which these laws obtain in respect to the friction of motion, and the accuracy with which the phenomenon of motion accord with them, may be judged of from one example taken from the first set of experiments of M. Morin upon the friction of surfaces of oak whose fibres were parallel to the direction of their motion upon one another. He caused the surfaces of contact to vary their dimensions in the ratio of 1 to 84, from less than 5 square inches to nearly 3 square feet; the forces which pressed them together he varied from 88 lbs. to 2205 lbs., and the velocities of their motion, from the slowest perceptible to 9·8 feet per second—causing them to be at one period accelerated motions, at another uniform, at a third retarded; yet throughout all this wide range of variation, he in no instance found the co-efficient of friction to deviate from the same fraction of 0·478 by more than $\frac{1}{24}$th of the amount of that fraction.

Table I.—Experiments on Friction, without Unguents.

The surfaces of friction were varied from ·03336 to 2·7987 square feet, the pressures from 88 lbs. to 2205 lbs., and the velocities from a scarcely perceptible motion to 9·84 feet per second.

Surfaces of Contact.	Friction of Motion. N.B.—The Friction in this case varies but very slightly from the mean.		Friction of Quiescence. N.B.—The Friction in this case varies considerably from the mean. In all the experiments the surface had been 15 minutes in contact.		Remarks. The surfaces of wood were planed, and those of metal filed and polished with the greatest care, and carefully wiped after every experiment. The presence of unguents was especially guarded against.
	Co-efficient of Friction.	Limiting Angle of Resistance.	Co-efficient of Friction.	Limiting Angle of Resistance.	
Oak upon oak, the direction of the fibres being parallel to the motion	0·478	25° 33′	0·625	32° 1′	
Oak upon oak, the directions of the fibres of the moving surface being perpendicular to those of the quiescent surface and to the direction of the motion	0·324	17 58	0·540	28 23	The dimensions of the surfaces of contact were in this experiment ·947 square feet, and the results were nearly uniform. When the dimensions were diminished to ·043, a tearing of the fibre became apparent in the case of motion, and there were symptoms of the combustion of the wood; from these circumstances there resulted an irregularity in the friction, indicative of excessive pressure.
Oak upon oak, the fibres of both surfaces being perpendicular to the direction of the motion	0·336	18 35			
Oak upon oak, the fibres of the moving surface being perpendicular to the surface of contact, and those of the surface at rest parallel to the direction of the motion	0·192	10 52	0·271	15 10	
Oak upon oak, the fibres of both surfaces being perpendicular to the surface of contact, or the pieces end to end	-	- -	0·43	23 17	
Elm upon oak, the direction of the fibres being parallel to the motion	0·432	23 22	0·694	34 46	
Oak upon elm, ditto	0·246	13 50	0·376	20 37	It is worthy of remark that the friction of oak upon elm is but 5-9ths of that of elm upon oak.
Elm upon oak, the fibres of the moving surface (the elm) being perpendicular to those of the quiescent surface (the oak) and to the direction of the motion	0·450	24 16	0·570	29 41	
Ash upon oak, the fibres of both surfaces being parallel to the direction of the motion	0·400	21 49	0·570	29 41	
Fir upon oak, the fibres of both surfaces being parallel to the direction of the motion	0·355	19 33	0·520	27 29	
Beech upon oak, ditto	0·360	19 48	0·53	27 56	
Wild pear-tree upon oak, ditto	0·370	20 19	0·440	23 45	
Service-tree upon oak, ditto	0·400	21 49	0·570	29 41	
Wrought-iron upon oak, ditto	0·619	31 47	0·619	31 47	In the experiments in which one of the surfaces was of metal, small particles of the metal began, after a time, to be apparent upon the wood, giving it a polished metallic appearance; these were at every experiment wiped off; they indicated a wearing of the metal. The friction of motion and that of quiescence, in these experiments, coincided. The results were remarkably uniform.
Ditto, the surfaces being greased and well wetted	0·256	14 22	0·649	33 0	
Wrought-iron upon elm	0·252	14 9	- -	- -	

Table I.—(*continued.*)

Surfaces of Contact.	Friction of Motion. N.B.—The Friction in this case varies but very slightly from the mean. Co-efficient of Friction.	Friction of Motion. Limiting Angle of Resistance.	Friction of Quiescence. N.B.—The Friction in this case varies considerably from the mean. In all the experiments the surface had been 15 minutes in contact. Co-efficient of Friction.	Friction of Quiescence. Limiting Angle of Resistance.	Remarks. The surfaces of wood were planed, and those of metal filed and polished with the greatest care, and carefully wiped after every experiment. The presence of unguents was especially guarded against.
Wrought iron upon cast iron, the fibres of the iron being parallel to the motion	0·194	10° 59′	0·194	10° 59′	
Wrought iron upon wrought iron, the fibres of both surfaces being parallel to the motion	0·138	7 52	0·137	7 49	
Cast iron upon oak, ditto . .	0·490	26 7			
Do., the surfaces being greased and wetted	- -	- -	0·646	32 52	
Cast iron upon elm	0·195	11 3			
Cast iron upon cast iron . . .	0·152	8 39	0·162	9 13	
Do., water being interposed between surfaces	0·314	17 26			
Cast iron upon brass . . .	0·147	8 22			
Oak upon cast iron, the fibres of the wood being perpendicular to the direction of the motion	0·372	20 25			
Hornbeam upon cast iron—fibres parallel to motion	0·394	21 31			
Wild pear-tree upon cast iron, ditto	0·436	23 34			
Steel upon cast iron . . .	0·202	11 26			
Steel upon brass	0·152	8 39			
Yellow copper upon cast iron . .	0·189	10 49			
Ditto oak . .	0·617	31 41	0·617	31 41	
Brass upon cast iron . . .	0·217	12 15			
Brass upon wrought iron, the fibres of the iron being parallel to the motion .	0·161	9 9			
Wrought iron upon brass . .	0·172	9 46			
Brass upon brass	0·201	11 22			
Black leather (curried) upon oak, ditto	0·265	14 51	0·74	36 31	The friction of motion was very nearly the same whether the surface of contact was the inside or the outside of the skin. The *constancy* of the co-efficient of the friction of motion was equally apparent in the rough and the smooth skins.
Ox hide (such as that used for soles and for the stuffing of pistons) upon oak, do.	rough 0·52 smooth 0·335	27 29 18 31	rough 0·605 smooth 0·43	31 11 23 17	
Leather as above, polished and hardened by hammering	0·296	16 30	-	- -	
Hempen girth, or pulley band (sangle de chanvre), upon oak, the fibres of the wood and the direction of the cord being *parallel* to the motion . . .	0·52	27 29	0·64	32 38	
Hempen matting, woven with small cords, do.	0·32	17 45	0·50	26 34	
Old cordage $1\frac{1}{2}$ inch in diameter, ditto	0·52	27 29	0·79	38 19	All the above experiments, except that with curried black leather, presented the phenomenon of a change in the polish of the surfaces of the friction—a state of their surfaces necessary to, and dependent upon, the state of their motion upon one another.
Calcareous oolitic stone, used in building, of a moderately hard quality, called stone of Jaumont—upon the same stone	0·64	32 38	0·74	36 31	
Hard calcareous stone of Brouck, of a light grey colour, susceptible of taking a fine polish (the muschelkalk), moving upon the same stone . . .	0·38	20 49	0·70	35 0	
The soft stone mentioned above, upon the hard	0·65	33 2	0·75	36 53	
The hard stone mentioned above, upon the soft	0·67	33 50	0·75	36 53	
Common brick upon the stone of Jaumont	0·65	33 2	0·65	33 2	
Oak upon ditto, the fibres of the wood being perpendicular to the surface of the stone	0·38	20 49	0·63	32 13	
Wrought iron upon ditto, ditto . .	0·69	34 37	0·49	26 7	
Common brick upon the stone of Brouck	0·60	30 58	0·67	33 50	
Oak as before (endwise) upon ditto .	0·38	20 49	0·64	32 38	
Iron, ditto ditto .	0·24	13 30	0·42	22 47	

Table II.—Experiments on the Friction of Unctuous Surfaces.

In these experiments, the surfaces, after having been smeared with an unguent, were wiped, so that no interposing layer of the unguent prevented their intimate contact.

Surfaces of contact.	Friction of motion.		Friction of quiescence.	
	Co-efficient of Friction.	Limiting Angle of Resistance.	Co-efficient of Friction.	Limiting Angle of Resistance.
Oak upon oak, the fibres being parallel to the motion	0·108	6° 10′	0·390	21° 19′
Ditto, the fibres of the moving body being perpendicular to the motion	0·143	8 9	0·314	17 26
Oak upon elm, fibres parallel	0·136	7 45		
Elm upon oak, ditto	0·119	6 48	0·420	22 47
Beech upon oak, ditto	0·330	18 16		
Elm upon elm, ditto	0·140	7 59		
Wrought iron upon elm, ditto	0·138	7 52		
Ditto upon wrought iron, ditto	0·177	10 3		
Ditto upon cast iron, ditto	- -	- -	0·118	6 44
Cast iron upon wrought iron, ditto	0·143	8 9		
Wrought iron upon brass, ditto	0·160	9 6		
Brass upon wrought iron	0·166	9 26		
Cast iron upon oak, ditto	0·107	6 7	0·100	5 43
Ditto upon elm, ditto, the unguent being tallow	0·125	7 8		
Ditto, ditto, the unguent being hog's lard and black lead	0·137	7 49		
Elm upon cast iron, fibres parallel	0·135	7 42	0·098	5 36
Cast iron upon cast iron	0·144	8 12		
Ditto upon brass	0·132	7 32		
Brass upon cast iron	0·107	6 7		
Ditto upon brass	0·134	7 38	0·164	9 19
Copper upon oak	0·100	5 43		
Yellow copper upon cast iron	0·115	6 34		
Leather (ox hide) well tanned upon cast iron, wetted	0·229	12 54	0·267	14 57
Ditto upon brass, wetted	0·244	13 43		

The distinction between the friction of surfaces to which no unguent is present, those which are merely unctuous, and those between which a uniform stratum of the unguent is interposed, appears first to have been remarked by M. Morin; it has suggested to him what appears to be the true explanation of the difference between his results and those of Coulomb. He conceives, that in the experiments of this celebrated engineer the requisite precautions had not been taken to exclude unguents from the surfaces of contact. The slightest unctuosity, such as might present itself accidentally, unless expressly guarded against —such, for instance, as might have been left by the hands of the workman who had given the last polish to the surfaces of contact —is sufficient materially to affect the co-efficient of friction.

Thus, for instance, surfaces of oak having been rubbed with hard dry soap, and then thoroughly wiped, so as to show no traces whatever of the unguent, were found by its presence to have lost $\frac{2}{3}$ds of their friction, the co-efficient having passed from 0·478 to 0·164.

This effect of the unguent upon the friction of the surfaces may be traced to the fact, that their motion upon one another without unguents was always found to be attended by a wearing of both the surfaces; small particles of a dark colour continually separated from them, which it was found from time to time necessary to remove, and which manifestly influenced the friction: now with the presence of an unguent the formation of these particles, and the consequent wear of the surfaces, completely ceased. Instead of a new surface of contact being continually presented by the wear, the same surface remained, receiving by the motion continually a more perfect polish.

Table III.—Experiments on Friction with Unguents interposed.

The extent of the surfaces in these experiments bore such a relation to the pressure, as to cause them to be separated from one another throughout by an interposed stratum of the unguent.

Surfaces of contact.	Friction of motion.	Friction of quiescence.	Unguents.
	Co-efficient of Friction.	Co-efficient of Friction.	
Oak upon oak, fibres parallel	0·164	0·440	Dry soap.
Ditto ditto	0·075	0·160	Tallow.
Ditto ditto	0·067	- -	Hog's lard.
Ditto, fibres perpendicular	0·083	0·254	Tallow.
Ditto ditto	0·072	- -	Hog's lard.
Ditto ditto	0·250	- -	Water.
Ditto upon elm, fibres parallel	0·136	- -	Dry soap.
Ditto ditto	0·073	0·178	Tallow.
Ditto ditto	0·066	- -	Hog's lard.
Ditto upon cast iron, ditto	0·080	- -	Tallow.
Ditto upon wrought iron, ditto	0·098	- -	Tallow.
Beech upon oak, ditto	0·055	- -	Tallow.
Elm upon oak, ditto	0·137	0·411	Dry soap.
Ditto ditto	0·070	0·142	Tallow.
Ditto ditto	0·060	- -	Hog's lard.

TABLE III.—(*continued.*)

SURFACES OF CONTACT.	FRICTION OF MOTION. Co-efficient of Friction.	FRICTION OF QUIESCENCE. Co-efficient of Friction.	UNGUENTS.
Elm upon elm, — fibres parallel	0·139	0·217	Dry soap.
Ditto upon cast iron, ditto	0·066	- -	Tallow.
Wrought iron upon oak, ditto	0·256	0·649	Greased, and saturated with water.
Ditto ditto	0·214	- -	Dry soap.
Ditto ditto	0·085	0·108	Tallow.
Ditto upon elm, ditto	0·078	- -	Tallow.
Ditto ditto	0·076	- -	Hog's lard.
Ditto ditto	0·055	- -	Olive oil.
Ditto upon cast iron, ditto	1·103	- -	Tallow.
Ditto ditto	0·076	- -	Hog's lard.
Ditto ditto	0·066	0·100	Olive oil.
Ditto upon wrought iron, ditto	0·082	- -	Tallow.
Ditto ditto	0·081	- -	Hog's lard
Ditto ditto	0·070	0·115	Olive oil.
Wrought iron upon brass, ditto	0·103	- -	Tallow.
Ditto ditto	0·075	- -	Hog's lard.
Ditto ditto	0·078	- -	Olive oil.
Cast iron upon oak, ditto	0·189	- -	Dry soap.
Ditto ditto	0·218	0·646	Greased, and saturated with water.
Ditto ditto	0·078	0·100	Tallow.
Ditto ditto	0·075	- -	Hog's lard.
Ditto ditto	0·075	0·100	Olive oil.
Ditto upon elm, ditto	0·077	- -	Tallow.
Ditto ditto	0·061	- -	Olive oil.
Ditto ditto	0·091	- -	Hog's lard & plumbago.
Ditto upon wrought iron	- -	0·100	Tallow.
Ditto upon cast iron	0·314	- -	Water.
Ditto ditto	0·197	- -	Soap.
Ditto ditto	0·100	0·100	Tallow.
Ditto ditto	0·070	0·100	Hog's lard.
Ditto ditto	0·064	- -	Olive oil.
Ditto ditto	0·055	- -	Lard and plumbago.
Ditto upon brass	0·103	- -	Tallow.
Ditto ditto	0·075	- -	Hog's lard.
Ditto ditto	0·078	- -	Olive oil.
Copper upon oak, fibres parallel	0·069	0·100	Tallow.
Yellow copper upon cast iron	0·072	0·103	Tallow.
Ditto ditto	0·068	- -	Hog's lard.
Ditto ditto	0·066	- -	Olive oil
Brass upon cast iron	0·086	0·106	Tallow.
Ditto ditto	0·077	- -	Olive oil.
Ditto upon wrought iron	0·081	- -	Tallow.
Ditto ditto	0·089	- -	Lard and plumbago.
Ditto ditto	0·072	- -	Olive oil.
Ditto upon brass	0·058	- -	Olive oil.
Steel upon cast iron	0·105	0·108	Tallow.
Ditto ditto	0·081	- -	Hog's lard.
Ditto ditto	0·079	- -	Olive oil.
Ditto upon wrought iron	0·093	- -	Tallow.
Ditto ditto	0·076	- -	Hog's lard.
Ditto upon brass	0·056	- -	Tallow.
Ditto ditto	0·053	- -	Olive oil.
Ditto ditto	0·067	- -	Lard and plumbago.
Tanned ox hide upon cast iron	0·365	- -	Greased, and saturated with water.
Ditto ditto	0·159	- -	Tallow.
Ditto ditto	0·133	0·122	Olive oil.
Ditto upon brass	0·241	- -	Tallow.
Ditto ditto	0·191	- -	Olive oil.
Ditto upon oak	0·29	0·79	Water.
Hempen fibres not twisted, moving upon oak, the fibres of the hemp being placed in a direction perpendicular to the direction of the motion, and those of the oak parallel to it	0·332	0·869	Greased, and saturated with water.
The same as above, moving upon cast iron	0·194	- -	Tallow.
Ditto ditto	0·153	- -	Olive oil.
Soft calcareous stone of Jaumont upon the same, with a layer of mortar, of sand, and lime, interposed after from ten to fifteen minutes' contact	- -	0·74	

A comparison of the results enumerated in the above table leads to the following remarkable conclusion, easily fixing itself on the memory, *that with the unguents hog's lard and olive oil interposed in a continuous stratum between them, surfaces of wood on metal, wood on wood, metal on wood, and metal on metal, when in motion, have all of them very nearly the same co-efficient of friction, the value of that co-efficient being in all cases included between* 0·07 *and* 0·08, *and the limiting angle of resistance therefore between* 4° *and* 4° 35′.

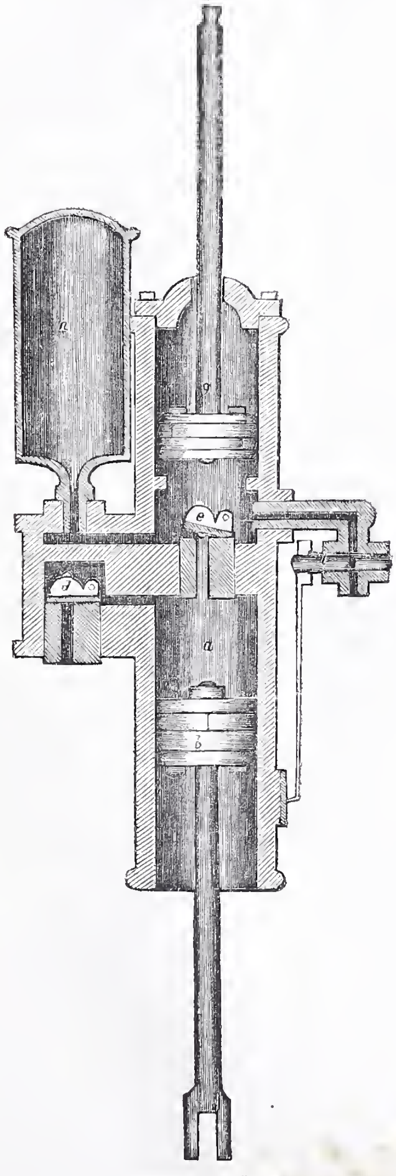
For the unguent tallow the co-efficient is the same as the above in every case, except in that of metals upon metals; this unguent seems less suited to metallic surfaces than the others, and gives for the mean value of its co-efficient 0·10, *and for its limiting angle of resistance* 5° 43′.

The experiments, of which the above are results, were all made under considerable pressures, such as those under which the parts of the larger machines are accustomed to move upon one another; under such pressures the adhesion of the unguent to the surfaces of contact, and the opposition presented to their motion by its viscidity, are causes whose influence may be altogether neglected as compared with the friction. In the case of lighter machinery—as, for instance, that of clocks and watches—these considerations rise, however, into importance.

NEIL'S PNEUMATIC GOVERNOR FOR STEAM ENGINES.

The species of governor figured and described below, has been attached to and worked on a high-pressure overhead-crank engine, and has answered the purpose intended most effectually. The apparatus occupies less space than the centrifugal governor, admits of ready application, and has a very neat and handsome appearance.

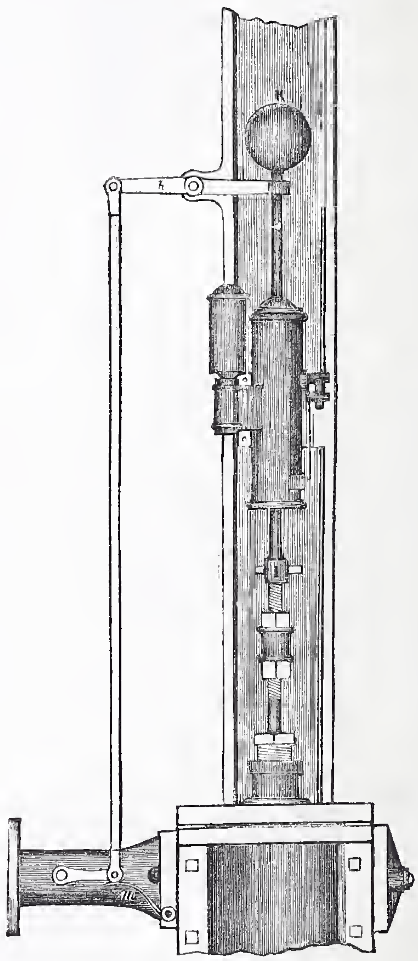
Fig. 1.



Section of the Governor.

In the subjoined drawings, the section, fig. 1, is made on a large scale, to explain more clearly the construction of the apparatus; figs. 2 and 3, which represent the apparatus in elevation, are intended to show its connection with the engine. Figs. 4 and 5 are full-sized sections of the piston packing-rings.

Fig. 2.



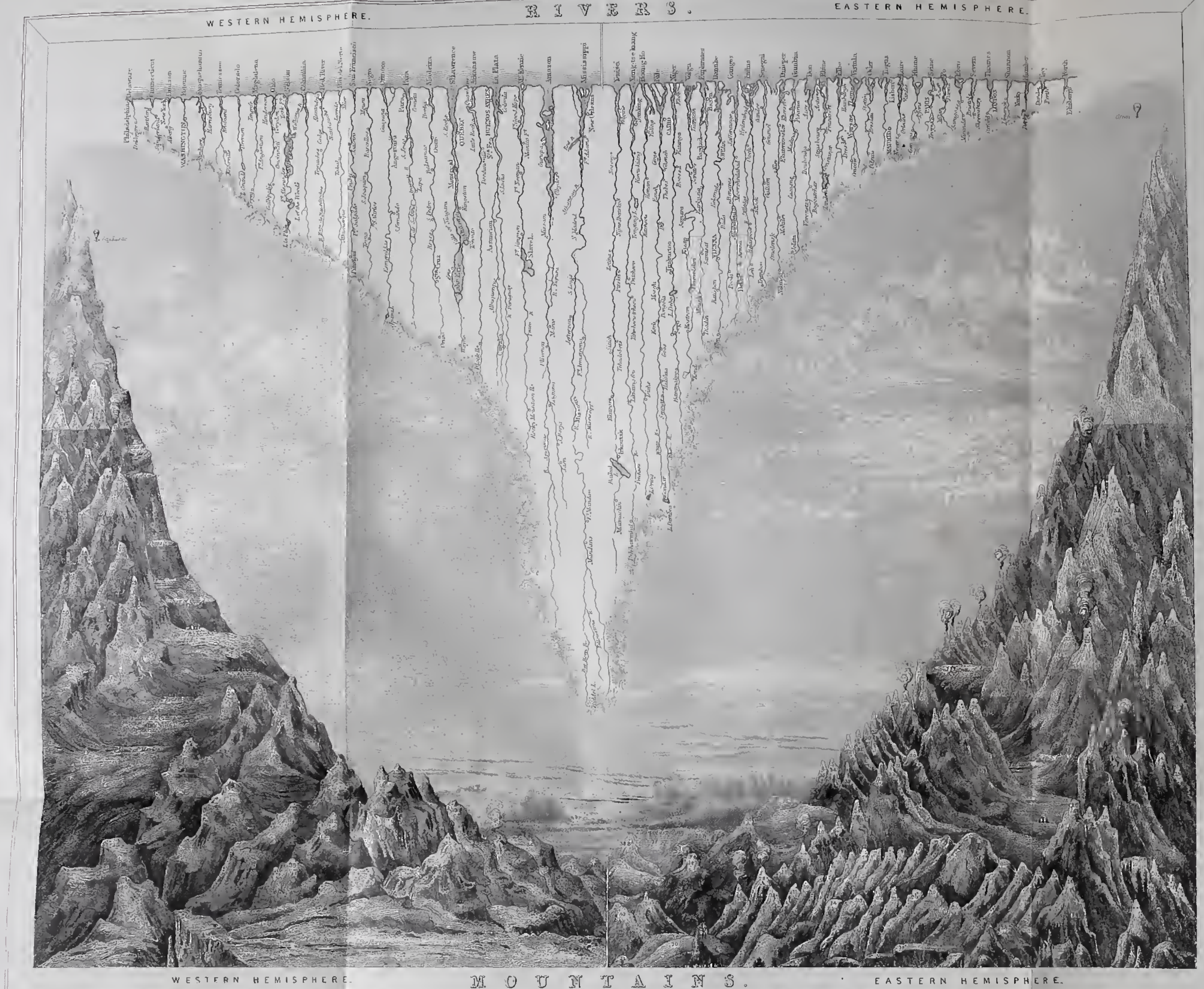
The cylinder, *a*, is bored perfectly smooth and parallel; the working piston, *b*, is fitted with two light elastic packing-rings, made of spring-steel, but not hardened. After the rings are properly fitted, the piston is ground longitudinally, with fine emery, into the working chamber; *d* is the air-receiving valve, having the lid faced with buff leather, and *e* the valve for discharging the air into the upper chamber of the cylinder. Into this chamber a floating piston, *g*, is fitted, having two small elastic rings, made also of spring-steel, and ground into the cylinder. The packing-rings, being very light of spring,

Races of Man - Northern Africa.

COMPARATIVE VIEW

OF THE

PRINCIPAL RIVERS AND MOUNTAINS OF THE WORLD.



PRINCIPAL MOUNTAINS.

WESTERN HEMISPHERE.

NORTH AND SOUTH AMERICA.

These form only one Group in the order of the Numbers.—The figures in this, and all the other Groups, answer to those in the order of the Table.

Name	Locality	Feet above Level of the Sea.
1 Nevada de Sorata	Andes of Peru and Bolivia	25,250
2 " d'Illimani—1st peak	Ditto	24,450
3 " " 2d peak	Ditto	24,200
4 Chimborazo	Ditto	21,440
5 Antisana	Ditto	19,150
6 Cotopaxi	Ditto	18,890
7 Arequipa (volc.)	Ditto	18,373
8 Descabecada	Ditto	18,000
9 Popocateptl	Mexico	17,716
10 Iliniza	Andes, Bolivia	17,376
11 Peak of Orizaba	Mexico	17,371
12 Tunguragun	Andes, Bolivia	16,579
13 Nevada de Merida	Colombia	16,420
14 Cerro de Potosi	Andes, Bolivia	16,000
15 Pichincha	Ditto	15,940
16 Nevado	Mexican Chain	15,700
17 Coffre de Perote	Ditto	13,514
18 Bighorn, or Long's Peak	Rocky Mountains	13,430
19 Mount St. Elias	Russian America	12,670
20 James's Peak	Rocky Mountains	11,500
21 Sierra de Cobré	Island of Cuba	9,000
22 Serrania Grande	" St. Domingo	9,000
23 Mount Fairweather	" Ditto	8,970
24 Blue Mountains	" Jamaica	7,486
25 Mount Washington	White Mts., New Hampsh.	6,650
26 Guadarrama	Colombia	6,400
27 White Mountains	New Hampshire	6,234
28 Blaarserk	East Greenland	6,000
29 Werner Mountains	East Greenland	6,000
30 Morne Garou	St. Vincent's, West Indies	5,110
31 Souffrière	Island of Guadaloupe	5,041
32 Moose Hillock	New Hampshire, U. States	4,630
33 Jorullo (volc.)	Mexico	4,267
34 Pelée	Martinique, West Indies	4,260
35 Camel's Rump	United States	4,000
36 Saddle Mountain	Ditto	4,000
37 Kaatskill	New York	3,454
38 Kellington Peak	Vermont	3,450
39 Grand Monadnock	New Hampshire	3,254
40 Appalachian Peak	United States	2,700
41 Cape Horn	Terra del Fuego	1,870
Gay Lussac's Balloon Ascent		23,500
Highest point reached by Humboldt		19,500
Mines of Potosi		16,080
Defile of Assuay		15,540
Highest snow-line of the Andes		15,100
Titicaca, Lake and Plains		12,800
Pass of Quindiu		11,500
City of Potosi		13,350
" Riobamba		10,800
" Quito		9,356
" Santa Fe d'Bogota	Colombia	8,650
Plains of Quito		8,000
City of Mexico	Mexico	7,470
Great Mexican Plateau	Mexico	7,000

EASTERN HEMISPHERE.

AFRICA.

Right-hand Group in Eastern Hemisphere.

1 Geesh	Abyssinia	15,000
2 Amid	Ditto	13,000
3 Cameroons	Biafra	13,000
4 Peak	Teneriffe	12,036
5 Lamalmon	Abyssinia	11,400
6 Miltsin	Morocco	11,200
7 Clarence Peak	Fernando Po	10,655
8 Nieuveldt	Cape of Good Hope	10,000
9 Compassberg	Ditto	10,000
10 Fogo (volc.)	Fogo, Cape Verde Islands	7,884
11 Taranta	Abyssinia	7,800
12 Volcano	Isle of Bourbon	7,680
13 Trigo	Canaries	7,400
14 Peak of Pico	Azores	6,900
15 Peak	Tristan d'Acunha	6,400
16 Khamies	Cape of Good Hope	5,300
17 Ruivo	Madeira	5,162
18 Komberg	Cape of Good Hope	5,000
19 Table Mountain	Ditto	3,582
20 Devil's Peak	Ditto	3,315
21 Green Mountains	Ascension Isle	2,868
22 Diana's Peak	St. Helena	2,692
23 Lion's Head	Cape of Good Hope	2,166
24 Cape of Good Hope	Ditto	1,000
25 Pyramid of Cheops	Egypt	720

ASIA.

Upper Group in Eastern Hemisphere.

1 Dhawalagbiri	Himalaya Mountains	26,862
2 Jewahir	Ditto	25,749
3 Jamautri	Ditto	25,500
4 Dhaiban	Ditto	24,740
5 Hindoo Khoosh	Ditto	20,800
6 Mowna Kaah	Hawai	18,400
7 Elburz	Caucasus	17,796
8 Ararat	Armenia	17,266
9 Klioutsherskoi	Kamtschatka	16,512
10 Mowna Roa	Owhyhee	16,020
11 Kazbec	Caucasus	15,345
12 Demawend	Irak	15,000
13 Ophir	Sumatra	13,840
14 Arjish Dagh	Asia Minor	13,100
15 Gunong Demp (volc.)	Sumatra	12,465
16 Egmont	New Zealand	11,433
17 Kouatskaia (volc.)	Kamtschatka	11,215
18 Bielukha	Altain Mountains	11,000
19 Peak	Otaheite	10,895
20 Krioaotskaia (volc.)	Kamtschatka	10,625
21 Shivelutsh (volc.)	Ditto	10,591
22 Parmesan	Banca	10,050

PRINCIPAL MOUNTAINS.

ASIA—Continued.

Name	Locality	Feet above Level of the Sea.
23 Lebanon	Syria	9,520
24 Awatska (volc.)	Kamtschatka	8,760
25 Dodabetta	Neilgherries	8,760
26 Oural	Ouralian Mountains	8,500
27 Pedrogalla	Ceylon	8,280
28 Melin	Qwang-tung, China	8,200
29 Peak of Jesso	Japan Islands	7,680
30 Sinai	Arabia Petræa	7,500
31 Adam's Peak	Ceylon	7,420
32 Olympus	Asia Minor	6,500
33 Western Ghauts	Deccan	6,500
34 Great Central Plateau of Asia		6,500
35 Oural Chain		5,500
36*a* Ida	Asia Minor	4,960
36*b* Corean Mountains	Corea	4,480
36*c* Ben-Lomond	Van Dieman's Land	4,200
37 Plain of Ispahan	Persia	4,140
38 Mount Wellington	Van Dieman's Land	3,795
38*a* Forest Hill	New South Wales	3,776
39 Carmel	Syria	2,116
Neilgherry District	Mysore	6,000 to 7,000

EUROPE.

Central Group in Eastern Hemisphere.

1 Mont Blanc	Alps	15,781
2 Mont Rosa	Alps	15,585
3 Ortler Spitze	Alps	15,430
3*a* Cervin	Alps	14,837
4 Furca	Alps	14,040
5 Jungfrau	Alps	13,720
6 Schreckhorn	Alps, Berne, Switzerland	13,397
7 Gothard	Alps, Switzerland	12,975
8 Mulahacen	Sierra Nevada, Spain	11,673
9 Cenis	Alps, Savoy	11,480
10 Perdu	Pyrenees	11,283
11 Great St. Bernard	Alps	11,006
12 Simplon	Alps	11,000
13 Ætna (volc.)	Sicily	10,963
14 Pic Blanc	Pyrenees	10,205
15 Little St. Bernard	Alps	9,594
16 Lomnitz	Carpathian	8,540
17 Orbelus	Greece	8,500
18 Guadarrama	Spain	8,500
19 Velino	Naples	8,397
20 Pindus	Albania	7,000
21 Mont d'Or	Puy de Dome	6,707
22 Athos	Roumelia	6,700
23 Olympus	Greece	6,500
24 St. Angelo	Lipari Islands	5,260
25 Dovrefeldt	Norway	4,875
26 Puy de Dome	France	4,750
27 Vesuvius (volc.)	Naples	3,978
28 Montserrat	Catalonia	3,300
28*a* Hecla (volc.)	Iceland	3,970
28*b* Stromboli (volc.)	Lipari Islands	3,002
29 Gibraltar	Andalusia	1,439
30 Valdai Hills	Russia	1,200
31 Mont Martre	Dep. of the Seine, France	400
Green's Balloon Ascent		27,600
Lake Lousaine		7,500
Hospital of St. Bernard		8,040
Convent of St. Gothard		6,810
Lake Luzon		6,220
Grimsel Hospital		6,000
Briançon		4,000
City of Madrid		1,900
City of Geneva		1,325
Lake Geneva		1,249
Lake Constance		1,162

THE BRITISH ISLES, &c.

Lowest Group in the Eastern Hemisphere.

1 Ben Mhuledhu	Aberdeenshire	4,418
2 Ben Nevis	Inverness-shire	4,358
3 Cairn Gorm	Ditto	4,050
4 Ben Lawers	Perthshire	3,944
5 Ben More	Sutherland	3,903
6 Ben More	Perthshire	3,818
7 Ben y Glo	Ditto	3,724
8 Ben Wyvis	Ross-shire	3,720
9 Ben Ledi	Perthshire	3,651
10 Snowdon	Caernarvonshire	3,571
11 Macgillicuddy's Reeks	Kerry, Ireland	3,410
12 Ben Voirlich	Perthshire	3,270
13 Skiddaw	Cumberland	3,022
14 Goat Fell	Arran	2,945
15 Cader Idris	Merionethshire	2,914
16 Broad Law	Peeblesshire	2,800
17 Croagh Patrick	Mayo	2,666
18 Cheviot	Northumberland	2,658
19 Hartfell	Dumfries	2,635
20 Paps of Jura	Argyleshire	2,470
21 Plinlimmon	Cardiganshire	2,463
22 Ingleborough	Yorkshire	2,361
23 Wharnside	Ditto	2,334
24 Pennigant	Ditto	2,272
25 Snaefell	Isle of Man	2,004
26 Pentland Hills	Mid Lothian	1,700
27 Campsie Hills	Stirlingshire	1,500
28 Malvern Hills	Worcestershire	1,444
29 Eildon Hills	Roxburghshire	1,300
30 Ailsa Craig	Firth of Clyde	1,139
31 Arthur's Seat	Mid Lothian	822
32 Dunnose	Isle of Wight	810
33 Holy Head	Anglesea	709
34 Beachy Head	Sussex	574
35 Salisbury Craigs	Mid Lothian	560
36 Dover Castle	Kent	469
37 Edinburgh Castle	Mid Lothian	434
38 Bass Rock	Firth of Forth	400
39 Greenwich Observatory	Kent	214
Ben Lomond	Stirlingshire	3,242
Director's House, Lead Hills	Lanark	1,280

PRINCIPAL RIVERS.

WESTERN HEMISPHERE.

Name.	Country.	Termination.	Length in Miles.
Mississippi,	United States,	Gulf of Mexico,	4,265
Amazon,	Brazil,	Atlantic Ocean,	4,000
Mackenzie,	British America,	Northern Ocean,	2,400
La Plata,	Brazil, &c.,	Atlantic Ocean,	2,350
Arkansas,	United States,	Mississippi,	2,000
St. Lawrence,	Canada,	Gulf of St. Lawrence,	2,000
Madeira,	Peru and Brazil,	Amazon,	1,800
Para,	Brazil,	Atlantic Ocean,	1,500
Orinoco,	Venezuela,	Atlantic Ocean,	1,480
Negro,	Brazil,	Amazon,	1,500
San Francisco,	Brazil,	Amazon,	1,500
Rio Del Norte,	Mexico,	Gulf of Mexico,	1,400
Red River,	New Mexico,	Mississippi,	1,500
Columbia,	United States,	Pacific Ocean,	1,000
Nelson,	British America,	Hudson's Bay,	900
Ohio,	United States,	Mississippi,	1,033
Magdalena,	New Grenada,	Caribbean Sea,	860
Colorado,	La Plata,	Atlantic Ocean,	850
Tennessee,	United States,	Ohio,	480
Ssquehanna,	United States,	Chesapeake Bay,	500

WESTERN HEMISPHERE—Continued.

Name.	Country	Termination.	Length in Miles.
Potomac,	United States,	Atlantic Ocean,	350
Hudson,	United States,	Atlantic Ocean,	325
Connecticut,	United States,	Atlantic Ocean,	310
Delaware,	United States,	Atlantic Ocean,	300

EASTERN HEMISPHERE.

Yenisei,	Siberia,	Northern Ocean,	3,000
Yang-tse, Kiang,	China,	Pacific Ocean,	3,200
Hoang Ho,	China,	Pacific Ocean.	2,600
Nile,	Nubia and Egypt,	Mediterranean Sea,	3,000
Niger,	Nigritia,	Gulf of Guinea,	2,300
Volga,	Russia,	Caspian Sea,	2,200
Euphrates,	Turkey in Asia,	Persian Gulf,	1,800
Danube,	Germany, &c.,	Black Sea,	1,700
Ganges,	Hindostan,	Bay of Bengal,	1,500
Indus,	Hindostan,	Indian Ocean,	1,700
Senegal,	Senegambia,	Atlantic Ocean,	1,000

EASTERN HEMISPHERE—Continued.

Name.	Country.	Termination.	Length in Miles.
Dnieper,	Russia,	Black Sea,	1,260
Gambia,	Senegambia,	Atlantic Ocean,	700
Don,	Russia,	Sea of Azof,	1,100
Rhine,	Switzerland, Germany, and Holland,	North Sea,	760
Elbe,	Germany,	North Sea,	690
Vistula,	Poland, &c.,	Baltic Sea,	628
Oder,	Prussia,	Baltic Sea,	550
Tagus,	Spain and Portugal,	Atlantic Ocean,	510
Loire,	France,	Bay of Biscay,	570
Rhone,	Switzerland and France,	Mediterranean Sea,	490
Seine,	France,	English Channel,	430
Po,	Italy,	Adriatic Sea,	450
Ebro,	Spain,	Mediterranean Sea,	420
Severn,	England,	Bristol Channel,	240
Thames,	England,	North Sea,	215
Shannon,	Ireland,	Atlantic Ocean,	224
Humber,	England,	North Sea,	180
Tay,	Scotland,	North Sea,	120
Forth,	Scotland,	North Sea,	115

have little tendency to wear the cylinder; those of the floating piston, in particular, should be so easy that they will close by a very slight pressure. The periphery of the rings of the floating piston are rounded, so as to have but a small bearing in the centre, on purpose to allow the rod to give a little from the perpendicular to suit the radius of the lever, *h*, one end of

Fig. 3.

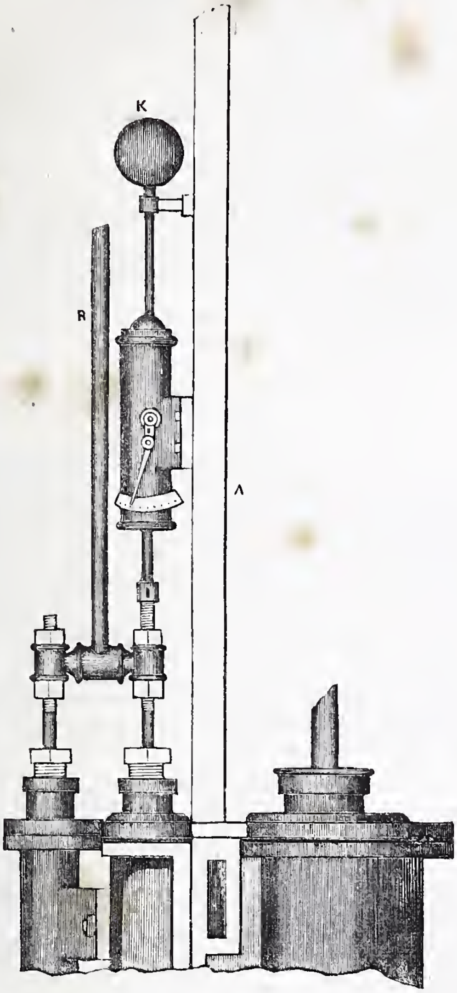


Fig. 4.

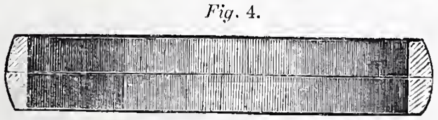


Fig. 5.

Full-sized sections of the Packing-rings of the Piston.

which bears upon the top of the rod, and is kept in contact by the weight of the ball, K, which is about eight pounds more than what is merely required to balance the friction of the piston and connecting-joints. The joints are all made quite easy, and, along with the floating piston, are worked without oil; the working piston only may have a little grease occasionally.

The air is discharged by the up-stroke of the piston, *b*, through the valve, *e*, and if the engine is working above her speed, overcomes the weight of the ball, and diminishes the opening of the throttle-valve; when the engine is working below her speed, the ball preponderates and opens the valve. *l* is a small cock, which forms a communication with the external atmosphere and the upper chamber, and is furnished with an index to regulate the amount of opening required to produce a certain number of strokes per minute of the engine. *m* is a spring to prevent the throttle-valve from shutting closer than will allow as much steam to pass as will keep the engine working at her proper speed, when not burdened. *n* is the air-vessel, for the purpose of condensing a body of air below the floating piston, to prevent it from giving back, between the strokes of the working piston.

The arrangement might be varied to suit different positions; the working piston might be above, the throttle-valve connections below, &c.

GEOGRAPHY.

CHAPTER III.

ON THE PRIMARY AND SECONDARY DIVISIONS OF LAND AND WATER ON THE EARTH'S SURFACE; AND ON THE CHARACTERISTIC PHYSICAL FEATURES OF THE OLD WORLD—EUROPE, ASIA, AND AFRICA.

It has been already stated, that the figure of the earth is a sphere or spheroid—being flattened or compressed at the poles, and somewhat bulged out towards the equator. Its polar diameter is therefore about 26 miles less than its equatorial diameter. Its mean diameter is estimated at 7,912 miles, and its superficial area at nearly 197,000,000 square miles. Of this area little more than *one-fourth* is dry land, the remaining portion, amounting to nearly *three-fourths* of the whole earth's surface, is covered with water, thus:—

Land,..........................	51,500,000	square miles.
Water,........................	145,500,000	" "
Earth's surface,........	197,000,000	" "

Had the earth been a perfectly smooth round globe, without either elevation or depression, there would have been no dry land at all; its whole external surface would have been covered with water. But by the operation of powerful forces, the Creator effected the elevation of a portion of this surface, which, in this manner, became *dry land* of various heights, and produced a corresponding depression of another portion, which thus became *sea* of various depths.

The mean elevation of the dry land above the sea, is computed to be under 1,000 feet, while the very highest points do not exceed *five and a half miles*. The depression of land constituting the depth of the sea, corresponds to the elevation of the land above its surface—the mean depth being considered not to extend beyond 1,000 feet, nor the greatest depth to exceed *five or six miles*.

To give a true representation of the surface of the earth, of its division into land and water, of the relative positions of their different portions, and of their comparative sizes and forms, we must have recourse to an artificial globe, upon which these various divisions can be accurately depicted, and their relative positions truly represented. It is impossible to represent any globe correctly on a flat surface, and on that account a *map*, which is a representation of the whole globe, or of some portion of its superficies upon paper, cannot convey to the mind an accurate conception of the surface of the earth, nor correctly represent the relative position of its different divisions. The student of geography ought, therefore, to be familiarized with the appearances and the relative positions of the different continents, peninsulas, islands, oceans, seas, and gulfs, as laid down on a good artificial globe, before his ideas become confused by the study of maps.

A map gives a more or less correct representation of any portion of the earth's surface, in proportion as the part represented is of small or large extent; if the portion represented is but of small extent, no error of any consequence will be committed by assuming its surface to be level; and so far,

maps are indispensable aids to the senses in enabling us to acquire a knowledge of the form, size, appearance, &c., of the various divisions of the surface of the earth.

The upper part, or top of a map, is called the *North;* the lower part, the *South;* the right side, the *East;* the left side, the *West.* A place is said to be *north* of one *below* it; *south* of one *above* it; *east* of one to the *left;* and *west* of one to the *right.*

The great natural divisions of the earth's surface are those of Land and Water; but they are farther subdivided as follows:—

Divisions of Land.	*Divisions of Water.*
Continent.	Ocean.
Country.	Sea.
Island.	River.
Peninsula.	Lake.
Promontory.	Gulf.
Cape.	Bay.
Isthmus.	Creek.
Coast, or	Strait.
Shore.	Channel.

The political divisions of the earth are principally Empires, Kingdoms, and Republics.

An *Empire* comprehends several countries or states, united under one ruler, who is generally styled an *Emperor.*

A *Kingdom* is a state or country governed by a *King.*

A *Republic* is a country governed by rulers chosen by the people.

A superficial glance at any map of the world, will show that there is much more land on the north than on the south side of the equator; that the great bulk of the different continents lie on the northern half of the globe, while the southern half is mainly covered by water. The proportions of land and water on the different sides of the equator are nearly as follows:—

	Square Miles.
Land on *North* side of the Equator,.........	38,000,000
Land on *South* side of the Equator,.........	13,500,000
Water on *North* side of the Equator,.......	60,500,000
Water on *South* side of the Equator,........	85,600,000

The extent of land on the north side of the equator, compared to that on the south side, is therefore nearly in the proportion of 3 to 1.

Although, as before mentioned, the representation cannot be correct, the whole surface of the globe is exhibited at one view on a map; and to accomplish this object on a plain surface, it is generally divided into two halves, or hemispheres —the *Eastern* and *Western* Hemispheres.

By this artificial division, the eastern hemisphere is made to comprehend the largest continental mass of land on the earth's surface—being that part, also, which has been known to mankind from the most remote antiquity—hence called the *Old World.* The continent of land on the western hemisphere is often called the *New World,* from its having been unknown to the inhabitants of the *Old,* till the celebrated voyage of Columbus, at the close of the 15th century.

Land.	Square Miles.
In Eastern Hemisphere, or Old World,.....	37,000,000
In Western Hemisphere, or New World,...	14,500,000

There are thus about *two and a half* times as much land on the eastern as on the western hemisphere.

Divisions of Land on the Earth's surface.—Till of late years, geographers almost invariably divided the dry land on the globe into four quarters, viz., Europe, Asia, Africa, and America; now, however, the following divisions are common, the last of which we shall adopt:—

1st. Europe, Asia, Africa, North America, South America, Australasia.

2d. Europe, Asia, Africa, North America, South America, Australasia, Polynesia.

3d. Europe, Asia, Africa, North America, South America, Oceania { *Malaysia. Australasia. Polynesia.* }

A glance at a map of the great eastern continent, or hemisphere, at once shows that it ought to be naturally divided into two continents; one portion of it—Africa—being joined to the rest by a very narrow neck of land, called the Isthmus of Suez, only 70 miles wide; this is separated from the other portion by the Mediterranean and Red Seas. The other part of the great mass of land on this hemisphere, however, is again divided into two continents, Europe and Asia; the division between these is more artificial, being the Black Sea, the Caspian Sea, the Sea of Marmora, a river, and two ranges of mountains.

The western hemisphere is naturally divided into two continents, North and South America, being connected by the narrow Isthmus of Panama, which, at one part, is only 28 miles from sea to sea.

Oceania, also called the Maritime World, is partly situated in both hemispheres, and comprehends *Australia,* and the numerous groups of islands in the Pacific Ocean.

The continents of Europe and Asia extend from east to west, their greatest length being parallel to the equator. The continents of Africa, North and South America, stretch from north to south.

The following is an approximation to the extent and population of these different divisions:—

Names.	Length.	Breadth	Area in Square Miles.	Population.
Europe	3,000 miles.	2,400 miles.	3,822,000	265,000,000
Asia	6,000 "	5,300 "	17,000,000	550,000,000
Africa....................	5,000 "	4,600 "	11,500,000	70,000,000
North America........	4,400 "	3,000 "	7,745,000	40,000,000
South America.........	4,700 "	3,200 "	6,500,000	18,000,000
Oceania	......	......	4,933,000	37,000,000
Total..................	......	......	51,500,000	980,000,000

The following are the divisions of the different continents, the position which these divisions occupy, their extent, population, and chief towns:—

EUROPE.

Name.	Position.	Area in Sq. Miles.	Population.	Capitals.
British Empire...........	W.	122,823	27,453,262	London.
France......................	W.	204,000	35,401,761	Paris.
Spain........................	S.W.	182,600	14,216,000	Madrid.
Portugal....................	S.W.	36,500	3,412,000	Lisbon.
Belgium....................	W.	11,417	4,359,090	Brussels.
Holland.....................	W.	13,227	3,267,638	Amsterdam.
Germany	Centre.	90,825	16,088,708	Frankfort.
Denmark...................	N.W.	21,856	2,296,597	Copenhagen.
Norway.....................	N.W.	122,752	1,328,471	Christiania.
Sweden.....................	N.W.	170,528	3,399,341	Stockholm.
Russia	N.N.E.	2,099,903	60,362,315	St. Petersburg.
Prussia......................	Centre.	108,350	18,346,625	Berlin.
Austria	Centre.	258,262	36,965,192	Vienna.
Switzerland	Centre.	15,315	2,392,740	Berne.
Italy	S.	119,493	23,961,429	Rome.
Turkey......................	S.E.	210,000	15,500,000	Constantinople.
Greece......................	S.E.	18,434	1,032,900	Athens.

ASIA.

Name.	Position.	Area in Sq. Miles.	Population.	Capitals.
Turkey......................	W.	450,000	16,000,000	Smyrna.
Arabia.....	S.W.	1,000,000	10,000,000	Mecca.
Persia........................	W.	450,000	9,000,000	Teheran.
Affghanistan..............	Centre.	400,000	6,000,000	Cabul.
Hindustan..................	S.	1,200,000	143,000,000	Calcutta.
Eastern Peninsula.......	S.E.	650,000	17,000,000	Ava.
China........................	S.E.	1,298,000	296,000,000	Pekin.
Tibet.........................	Centre.	750,000	5,000,000	Lassa.
Chinese Tartary..........	E.	3,300,000	12,000,000	Kirin-Oula.
Independent Tartary....	Centre.	750,000	5,000,000	Bokhara.
Asiatic Russia............	N.	5,000,000	6,000,000	Tobolsk.
Japan	E.	260,000	25,000,000	Jeddo.

AFRICA.

Name.	Position.	Area in Sq Miles.	Population.	Capitals.
Egypt	N.E.	150,000	2,500,000	Cairo.
States of Barbary: Tripoli	N.	9,720	1,500,000	Tripoli.
States of Barbary: Tunis	N.	3,600	2,000,000	Tunis.
States of Barbary: Algeria	N.W.	9,000	2,808,000	Algiers.
States of Barbary: Morocco	N.W.	220,000	8,500,000	Morocco.
Senegambia	W.	200,000	Unknown	Fort St. Louis.
Upper Guinca	W.	330,000	Unknown	Cape C. Castle.
Lower Guinea	W.	380,000	Unknown	Loango.
Cape Colony	S.	200,000	179,700	Cape Town.
Natal	S.E.	18,000	125,000	Pietermaritz-[burg.
Sofala	S.E.	Unknown	Unknown	Sofala.
Mozambique	S.E.	230,000	Unknown	Mozambique.
Zanquebar	E.	Unknown	Unknown	Zanzibar.
Ajan	E.	Unknown	Unknown	Magadoxo.
Abyssinia	E.	37,000	3,000,000	Gondar.
Nubia	E.	60,000	400,000	Khartouin.
Sahara	Centre.	2,500,000	Unknown	......
Fezzan	N.	180,000	75,000	Mourzouk.
Nigritia, or Soudan: Bambarra	Centre.	Unknown	Unknown	Sego.
Nigritia, or Soudan: Timbuctoo	Centre.	Unknown	Unknown	Timbuctoo.
Nigritia, or Soudan: Houssa	Centre.	Unknown	5,000,000	Sackatoo.
Nigritia, or Soudan: Bornou	Centre.	Unknown	Unknown	Kouka.
Nigritia, or Soudan: Darfur, &c.	Centre.	Unknown	Unknown	Cobbe.

NORTH AMERICA.

Name.	Position.	Area in Sq. Miles.	Population.	Capitals.
British America / Indian Countries	N.N.E. / N.N.W.	2,550,000	2,652,000	Toronto.
Russian America	N.W.	371,000	61,000	......
United States	S.E. & Centre.	3,260,000	23,000,000	Washington.
Mexico	S.	1,100,000	7,200,000	Mexico.
Central America	S.	203,000	2,146,000	Guatemala.

SOUTH AMERICA.

Name.	Position.	Area in Sq Miles.	Population.	Capitals.
Colombia: New Granada	N.W.	380,000	1,700,000	Panama.
Colombia: Venezuela	N.	450,000	900,000	Caraccas.
Colombia: Ecuador	W.	212,000	600,000	Quito.
Guiana	N.	136,000	198,000	Cayenne.
Brazil	N.E.& Centre.	2,300,000	7,560,000	Rio Janeiro.
Peru	W.	524,000	1,400,000	Lima.
Bolivia	W. & Centre.	318,000	1,700,000	Chuquisaca.
Chili	W.	144,000	1,200,000	Santiago.
La Plata	S.E.	927,000	675,000	Buenos Ayres.
Paraguay	Centre.	74,000	250,000	Assumption.
Uruguay, or Banda Oriental	S.E.	120,000	140,000	Monte Video.
Patagonia	S.	380,000	120,000	Port St. Julian.

OCEANIA.

AUSTRALASIA.

Name.	Position.	Area in Sq Miles.	Population.	Capitals.
Australia	S.E. of Asia.	3,000,000	500,000	Sidney.
Van Dieman's Land	S. of Australia.	27,000	70,164	Hobart Town.
New Zealand	S.E. of Australia.	95,000	140,000	Auckland.
New Guinea	N. of Australia.	200,000	Unknown	......
New Britain	E. of New Guinea.	12,000	Unknown	......
New Ireland	N.E. of N. Britain.	3,000	Unknown	......
Solomon Islands	S.E. of N. Britain.	Group.	Unknown	......
New Hebrides	S.E. of N. Britain.	Gr. of sm. isl.	Unknown	......
New Caledonia	E. of Australia.	7,000	Unknown	......
Norfolk Island	E. of Australia.	Small.	2,000	......
Auckland Islands	S. of New Zealand.	Group.	Unknown	......

MALAYSIA, OR ASIATIC ISLANDS.

Name.	Position.	Area in Sq Miles.	Population.	Capitals.
Island of Sumatra	off S. point of Asia	165,000	2,500,000	Bencoolen.
Island of Java	do.& E.of Sumatra	50,000	10,000,000	Batavia.
Island of Borneo	do. & N. of Java.	300,000	3,000,000	Borneo.
Island of Celebes	E. of Borneo.	73,000	3,000,000	Macassar.
The Moluccas, or Spice Islands	E. of Celebes.	Large group.	Unknown	......
The Philippines, &c.	N. of Borneo.	120,000	5,000,000	......

POLYNESIA, OR ISLANDS IN THE PACIFIC OCEAN.

Name.	Position.	Extent.	Population.
Pelew Islands	E. of Philippine Islands.	Gr. of Sm. Islands.	Unknown
Ladrone, or Marian Islands	E. of Philippine Islands.	Gr. of Sm. Islands.	10,000
Caroline Islands	E. of Philippine Islands.	About 30 in numb.	Unknown
Navigators' Islands	N.E. of Friendly Islands.	Small Group.	Unknown
Friendly Islands	S.W. of Society Islands.	Numerous Group.	80,000
Cook's Islands	Betw. Do. & Friendly Isl.	Small Group.	50,000
Society Islands	Betw. Austr. & S. Amer.	Large Group.	20,000
Low Archipelago	E. of Society Islands.	Numerous Group.	Unknown
The Marquesas	N.E. of Society Islands.	Group.	40,000
Sandwich Islands	Betw. N. Amer. & Austr.	13 in number.	100,000

Divisions of Water on the Earth's Surface.—As, in strict language, there are only *two* great continents of land, so, properly speaking, there is only *one* great ocean, which covers seven-tenths of the globe. For the sake of convenience, however, this great body of salt water has been divided into *five* oceans, which have received different names, and which are, in some degree, separated from one another by the large masses of land. These are—the ATLANTIC OCEAN, the PACIFIC OCEAN, the INDIAN OCEAN, the NORTHERN or ARCTIC OCEAN, and the SOUTHERN or ANTARCTIC OCEAN.

The ATLANTIC OCEAN is bounded by the continents of Europe and Africa on the east, and the continents of North and South America on the west.

The PACIFIC OCEAN covers more than half the globe, and is bounded on the east by the continents of North and South America, and on the west by the eastern shores of Asia, Australia, &c.

The INDIAN OCEAN lies between the shores of India on the north, and the great Southern or Antarctic Ocean on the south; the continent of Africa bounds it on the west, and that of Australia on the east.

The NORTHERN or ARCTIC OCEAN lies north of the great continents and of the Arctic circle, and surrounds the North Pole.

The SOUTHERN or ANTARCTIC OCEAN surrounds the South Pole, and lies south of the Antarctic circle.

The following is a rough approximation to the extent and areas of these different oceans :—

Name.	Greatest Breadth.	Area in Square Miles.
ATLANTIC OCEAN	5,000 miles.	25,000,000
PACIFIC OCEAN	12,000 "	50,000,000
INDIAN OCEAN	4,500 "	20,000,000
ARCTIC OCEAN	2,000 "	15,500,000
ANTARCTIC OCEAN	......	35,000,000

The following are the principal branches, divisions, or prolongations of these different oceans, and the position they occupy :—

ATLANTIC OCEAN.

I.—ON THE WESTERN OR AMERICAN SIDE OF THE ATLANTIC.

Name.	Direction of Length.	Position.
Baffin's Bay	N.N.W.	A long inland sea, W. of Greenland, often ice-bound.
Davis' Straits	N.	Connects Baffin's Bay to the Atlantic Ocean.
Hudson's Bay	N.	A large inland sea, penetrating the N. of North America.
Arms of Hudson's Bay: Hudson's Strait	W.N.W.	Connects the above with the Atlantic.
Arms of Hudson's Bay: Fox's Channel	N.N.E.	Connects Hudson's Bay with Boothia Gulf by Fury and Hecla Strait.
Arms of Hudson's Bay: James's Bay	N.	South arm of Hudson's Bay.
Arms of Hudson's Bay: Chesterfield Inlet	W.	A long narrow arm of ditto, penetrating the land on the west.
Gulf of St. Lawrence	N.E.	Lies at the mouth of the river St. Lawrence.
Bay of Fundy	N.N.E.E.	Between Nova Scotia and the mainland.
Chesapeake Bay	N.	In Virginia, United States, extends N. 200 miles.
Gulf of Mexico	W.	Large inland sea, between Central America and United States.
Caribbean Sea	W.	Large sea, between West Indies and continent of South America.

II.—ON THE EASTERN OR EUROPEAN SIDE OF THE ATLANTIC.

	Name.	Direction of Length.	Position.
	Baltic Sea	N.N.W.	Large inland sea, in N. of Europe, separating Prussia and Russia from Sweden.
Arms of Baltic Sea.	Gulf of Bothnia	N.N.W.	The northern arm of the above, separating Sweden from Finland.
	Gulf of Finland	E.	Eastern arm of Baltic—at the east extremity is situated St. Petersburgh.
	Cattegat	S.S.E.	Between Sweden and Denmark.
	Skager Rack	E.N.E.	Connects Baltic Sea with German Ocean.
	North Sea or German Ocean	N.	Between Great Britain on W., and Denmark and Norway on E.
	St. George's Channel	N.E.	Between England and Ireland.
	English Channel	E.N.E.	Between England and France.
	Straits of Dover	N.E.	Ditto, and connects English Channel with German Ocean.
	Bay of Biscay	E.	W. of France and N. of Spain—large and dangerous bay.
	Mediterranean Sea	E.	Largest inland sea in the world, lying between Europe and Africa, 2,500 miles long.
Gulfs and Branches of the Mediterranean Sea.	Straits of Gibraltar	E.	Connects Mediterranean with Atlantic; only 8 miles wide.
	Gulf of Lyons	N.E.	Off south coast of France.
	Gulf of Genoa	S.E.	Off south coast of Northern Italy.
	Gulf of Venice	N.W.	Between Italy and Turkey in Europe; 550 miles long, 120 wide.
	Sea of Marmora	E.	Between Black Sea and Archipelago; connected with former by Bosphorus.
	Dardanelles	N.E.	Anciently *Hellespont*; very narrow strait, between former and Archipelago.
	Black Sea	E.	Anciently *Euxine* Sea; between Russia in Europe and Asia Minor—large.
	Sea of Azof	N.E.	Arm of Black Sea, penetrating south of Russia—small.
	Archipelago	S.	Anciently *Ægean* Sea; between Asia Minor and Greece.
	Levant		Off W. coast of Syria—a name given to eastern part of Mediterranean.
	Gulf of Guinea		Off W. coast of Africa.

PACIFIC OCEAN.

I.—ON THE WEST SIDE OF THE PACIFIC.

Name.	Position.
Sea of Kamtchatka	Between N.E. shores of Siberia and N. America.
Sea of Okhotsk	Between the Kamtchatka peninsula and Chinese empire.
Sea of Japan	Between Japan islands and Chinese empire.
Yellow Sea	Between China Proper and peninsula of Corea.
Chinese Sea	Between S.E. shores of Asia and the Asiatic islands.
Parts of Chinese Sea. Gulf of Tonquin	A prolongation of the Chinese Sea, S. of China.
Parts of Chinese Sea. Gulf of Siam	A prolongation of the Chinese Sea, E. of eastern peninsula.
Java Sea	Between Java and Borneo.
Celebes Sea	Between Celebes and the Philippine islands.
Gulf of Carpentaria	Penetrates the nothern coast of Australia.

II.—ON THE EAST SIDE OF THE PACIFIC.

Name.	Position
Gulf of California	Between the peninsula of Lower California and Mexico.
Gulf of Panama	South of the isthmus of Panama.

INDIAN OCEAN.

Name.	Position.
Bay of Bengal	Between Hindustan and Eastern Peninsula.
Gulf of Maccaban	Part of the above, jutting into E. Peninsula.
Persian Gulf	Penetrates Asia, N.W., for 550 miles, between Arabia and Persia.
Red Sea	Extends between Asia and Africa, N.W., for 1,420 miles.
Arabian Sea	Between Arabia and Hindustan.
Channel of Mozambique	Between island of Madagascar and coast of Africa.

ARCTIC OCEAN.

Name.	Position.
White Sea	Penetrates European Russia on north.
Sea of Kara	Between islands of Nova Zembla and Asiatic Russia.
Behring's Straits	Between continents of Asia and North America.
Wellington Channel	Between Cornwallis island and North Devon.
Barrow Straits	Between Cornwallis island and Boothia Felix.
Prince Regent's Inlet	Between Boothia Felix and South Devon.
Gulf of Boothia	A prolongation southward of P. Regent's Inlet.
Lancaster Sound	A channel leading from Baffin's Bay to Barrow Straits.

PROMINENT FEATURES OF THE SEVERAL CONTINENTS OF LAND ON THE EARTH'S SURFACE.

I.—PHYSICAL ASPECT OF EUROPE.

From the number of deep bays, gulfs, and estuaries, which penetrate the continent of Europe on the three sides—north, west, and south—on which it is bounded by sea, it presents a much greater extent of coast, in proportion to its surface, than any other of the great divisions of the globe, and it is thus stamped with features different from all the others. Not only do these seas, bays, and gulfs, by which it is indented, greatly modify and soften those rigours of climate which are inseparable from high northern latitudes, but they afford ready means of intercommunication, they prove highly favourable for commerce and navigation, and no doubt have greatly contributed to render this continent so much superior in civilization and opulence to the other divisions of the globe.

The length of European coast, from the Straits of Waigatz to the Sea of Azof, is about 17,000 miles.

The *physical aspect* of Europe presents a great variety; but taking a comprehensive view of the surface of this continent, it may be divided into three portions—*two mountain systems, and an immense level plain.* This plain occupies nearly two-thirds of the whole continent, the remaining third being partly covered with high mountains, and partly with hills and eminences of moderate height.

The comparative areas of these different portions have been stated to be as follows:—

	Area in Square Miles.
The Great Plain	2,500,000
The Scandinavian, or Northern Mountain System	300,000
The Southern Mountain System	1,000,000

The Great Plain.—This plain commences at the shores of the German Ocean on the west, where it includes Holland, Denmark, the greater part of Belgium, and parts of France, and where the land does not rise, in almost any part, more than 100 feet above the level of the sea. It extends eastward through Northern Germany, Prussia, Poland, and over the greater part of Russia, towards the Ural mountains, where the land rises in elevated plains or *steppes*. So low, indeed, is this extensive plain, that if the Atlantic Ocean were to rise two hundred and fifty fathoms above its present level, its whole surface would be submerged, and nearly two-thirds of Continental Europe buried under the waters of the ocean.

The Scandinavian, or Northern Mountain System.—This portion comprehends Sweden and Norway, or what is denominated the Scandinavian peninsula; it rises, on the western side, to the height of some hundred feet close to the sea, and speedily becomes a huge mountain-mass, attaining a general elevation of from 3,000 to 4,000 feet, and rising in some parts to a height of 8,000 feet above the level of the sea. The north-western portion of this peninsula constitutes a mountain range, running parallel to the ocean; towards the southern extremity, this ridge spreads out into an elevated plain, from 100 to 150 miles across, and attains, in many parts, an altitude of 4,200 feet, being somewhat above the line of perpetual congelation.

The Southern European Mountain System.—The remaining kingdoms of Europe—comprising parts of France and Germany, the whole of Spain, Portugal, Switzerland, Austria, Italy, Turkey, and Greece—are more or less elevated, presenting a surface more diversified, more picturesque, and, unless in mountainous parts, more cultivated than any other portion of the globe of equal extent. It includes the high mountain range of the Pyrenees, which separates the Spanish peninsula from the rest of Europe; the elevated central table-land, by which the greater part of that peninsula is occupied; the great Alpine mountain system, with its numerous branches and offsets; the Apennines in Italy; the Carpathian mountains in Austria; and the mountains of Turkey and Greece.

II.—PHYSICAL ASPECT OF ASIA.

The continent of Asia presents every species of diversity in its physical appearance. We have, on this division of the globe, the low swampy jungle, and the highly elevated plateau; the barren desert, and the fertile and luxuriant plain and valley; regions clothed with the richest verdure, extensive tracts scorched and burned up with heat and

drought, and others dreary, ice-bound, and sterile; lakes below the sea-level, rivers the largest, and mountains the highest on the earth's surface; and from its early history—from its being the cradle of the human race—it is altogether the most interesting of the great divisions of the globe.

Although it is more than four times the size of Europe, its length of coast line is little more than double that of the latter continent, being under 35,000 miles.

The physical geography of Asia divides this continent into the following regions:—

	Area in Square Miles.
1. Central Asia—	
The eastern plateau, or system of table-lands	7,600,000
The western plateau, or system of table-lands	1,300,000
2. The Lowlands of Asia	5,000,000
3. The valleys intervening between these two regions	3,100,000

1. Central Asia.—This extensive region occupies more than two-fifths of the whole continent; and although it contains two systems of table-lands, different both in extent and elevation, they merely constitute two terraces—a higher and a lower; and it may therefore be considered as one elevated protuberance of the earth's surface. It extends from the Black Sea and the Persian Gulf on the *west*, to the mountain ranges of Western China and the shores of the Sea of Japan on the *east*, being a distance of more than 5,500 miles. It is bounded by the Altai mountains on the *north*, and by the Himalaya mountains on the *south*, varying in breadth from 1,800 to 2,000 miles.

The Eastern Plateau comprehends the table-land of Tibet, that of the great desert called Gobi, and the countries lying between them; and it rises from 4,000 to 14,000 feet above the level of the sea, while some of the culminating points on the bounding and intersecting ranges of mountains rise to a height of 20,000, 25,000, 28,000; and one of them, Kunchinginga, in the Himalayan range, the highest mountain on the globe, to 28,177 feet.

The Western Plateau comprehends the table-lands of Iran (Persia) and Afghanistan; the former under 4,000 feet in elevation, and the latter rising to about 7,000 feet above the level of the sea.

Besides the above, there is the plateau of the *Deccan*, or interior of *Hindustan*, about 3,000 feet; that of *Armenia*, about 6,000 feet; and those of the interior of *Asia Minor* and *Arabia*, attaining a considerable elevation above the sea.

2. The Lowlands of Asia.

1st. The great *Chinese Lowland*, extending along the shores of the Pacific Ocean on the eastern coast of Asia: it is everywhere intersected with canals; internal navigation and agriculture are in the most active and advanced state; and, in an agricultural point of view, it is the richest and most populous country on earth.

2d. *Indo-Chinese Lowland.*—It is occupied by the kingdom of Siam, and part of Cochin-China. This lowland is singularly well adapted for the culture of rice.

3d. *The Lowland of Hindustan.*—It lies in the north-east, between the Deccan and the Himalaya mountains.

4th. *The Lowland of Syria and Arabia.*—Its southern portion is a dry and parched-up desert; its northern half is fertile, being watered by the rivers Euphrates and Tigris, and their tributaries.

5th. *The Siberian Lowland.*—This is by far the most extensive lowland in Asia; its area is more than half that of all the others put together. It lies between the Altai mountain range and the Arctic Ocean, along the shores of which it extends from the Ural Mountains on the west, to Behring's Straits on the east. From its high northern latitude, the greater portion of it is extremely cold and sterile, notwithstanding its being watered by large and numerous rivers.

6th. *The Lowland of Bucharia.*—This comprehends the country around the Sea of *Aral*, in Turkestan, and it extends from Tibet to the banks of the Volga. It is composed of extensive sandy and barren plains, called *steppes*, covered with grass, with a few tracts of arable land here and there. It is inhabited by nomadic tribes, who wander from place to place in search of food.

3. The Intervening Valleys.—The mountain ranges which bound the table-lands of Asia, descend to the lowlands by an extensive system of terraces, through which the original tributaries of the great river systems descend to the level plains below. Through those gradual slopes and diversified terraces, these streams and mountain torrents excavate numerous valleys, which constitute the intervening region between the highlands and lowlands of Asia.

III.—PHYSICAL ASPECT OF AFRICA.

Like most of the extensive portions of land on the earth's surface, Africa rises from many parts of the coast to the interior by a succession of steps or terraces, which spread out into widely-extended plains. This configuration of surface is distinctly seen, in the southern portion of the continent, at Cape Colony; on the eastern side, in Abyssinia; and inferred in other parts by the regular series of falls in the beds of the great rivers.

The most remarkable feature in the physical aspect of Africa, however, is the *Sahara*, or *Great Desert*—a vast expanse of burning sands, which overspreads its whole surface like an ocean, or broad belt, and is only interrupted by the narrow valley of the Nile. The physical geography of Africa, therefore, divides the continent into *three* portions:—

	Area in Sq. Miles.
1. The Sahara, or Great Desert	2,500,000
2. The country between the Desert and Mediterranean	600,000
3. The country south of the Great Desert	8,400,000

1. *The Sahara, or Great Desert.*—It extends from the shores of the Atlantic Ocean on the west, to the valley of the Nile on the east—a length of nearly 3,000 miles; its breadth extends from Cape Nun to the mouth of the river Senegal on the Atlantic coast, and, in the interior of the continent, from the Atlas range of mountains on the north, to a line varying between the 14th and 17th degrees of north latitude—the average width, north to south, is about 1,000 miles. This extensive and desolate region consists of level tracts of loose drifting sand, unrelieved by a single shrub, and unrefreshed, for hundreds of miles, by a single spring or drop of water; of other tracts of low sand-hills, valleys, and projecting rocks, and of districts covered more or less with gravel and pebbles, producing acacias, brambles, and other thorny shrubs; and of *oases*, or fertile tracts of light pulverulent soil, which support a moderate population, are watered with springs, contain extensive groves of palms, dates, pomegranates, &c., and fields where millet is grown. "Now the naked rock," says Humboldt, "appears to view perfectly smooth and level, where the traveller may pass over for days together without meeting even a single grain of sand, where one sees only the heavens above, and the hard stone pavement beneath; now we behold a flat plain covered with rolled pebbles, here and there intersected with ravines and valleys extending to about thirty feet below the surface; and now an ocean of sand presents itself, frequently containing so large a quantity of salt, that whole tracts appear coated with it, and resemble fields of ice. Occasionally, spots of verdure are found, known under the name of oases, which display palm trees and springs of water."

In those tracts which are covered with loose sand, whirlwinds often prevail with great fury, raising the sand in dense clouds and floating mountains, which flit from place to place with great force and rapidity, and bury the unfortunate caravan, or cafilla, which may come in their way, in speedy and irretrievable ruin.

"Lo! where our wide Numidian wastes extend,
Sudden the impetuous hurricanes descend,
Which through the air in circling eddies play,
Tear up the sands, and sweep whole plains away;
The helpless traveller, with wild surprise,
Sees the dry desert all around him rise,
And smothered in the dusty whirlwind dies."—*Addison.*

2. *The country between the Desert and the Mediterranean.*—This region is wholly composed of the Atlas chain of mountains, with its subordinate ridges, and comprehends the several states of Barbary—Tripoli, Tunis, Algeria, and

Morocco; Fezzan, a country bordering upon Tripoli on the south, is considered an oasis or island in the Great Desert. From Mount Hentet—the culminating point in the Atlas range, which attains a height of 15,000 feet, and is said to be permanently covered with snow—the hills fall towards the Atlantic in Morocco, and the country becomes a level plain; eastward, however, through Algeria, Tunis, and Tripoli, the country is hilly, and its surface diversified by valleys and ravines. Between the Atlas chain of mountains and the Mediterranean Sea, the aspect of the country is somewhat assimilated by its soil, climate, and productions, to that of Southern Europe; but between these mountains and the Desert, the climate is dry and burning, and the soil passes insensibly into sand.

3. *The country south of the Great Desert.*—An extensive range of mountains stretches across the whole continent of Africa, from the British colony of Sierra Leone on the west coast, to the southern boundary of Abyssinia, near the Straits of Babelmandel, on the east. This range is entitled the Kong mountains, on the west, in Upper Guinea; the Cameroon mountains, on the east of the river Quorra or Niger; and the Jebel Kumrah, the Donga mountains, or the mountains of the Moon, in the centre of Africa, where they are very imperfectly known. This region comprehends these mountains, the country between them and the Great Desert, (the greater part of which is denominated Nigritia, Central Africa, or Soudan), the large triangular portion of the continent south of these mountains, which, with the exception of small portions of the coast, is almost entirely unexplored, and where we might with equal reason, as

———— "In ancient maps,
Place elephants to fill up gaps."

Central Africa, north of the chain of mountains above described, was, till lately, a *terra incognita* to geographers; but the curiosity and enterprise of modern travellers have overcome the scorching heats of a burning climate, the privations to which travellers over extensive deserts are exposed, and the dangers to be dreaded and encountered in passing through nations and hordes of savage and blood-thirsty barbarians; and many parts of this extensive region have now been explored by Mungo Park, Denham and Clapperton, and by Lander and Caillié. By these travellers it has been discovered that it is more fertile, better cultivated, and inhabited by races much more civilized than most of the countries previously known. Wherever it is watered by rivers, or the desert interrupted by mountains or valleys, there occur spots of the most luxuriant fertility, enjoying a mild climate, and quite capable of maintaining the dense population with which they are inhabited. Of the unexplored region to the south of the above-mentioned range of mountains, all that is known of the interior is, that it is skirted on the east by the chain of Lupata mountains, or the "Backbone of the World," which runs, in almost an unbroken series, parallel to the coast of the Indian Ocean; on the south, it is bounded by the hills of Cape Colony; on the west, by Lower Guinea, which in some parts is rocky, in others arid and sandy, and at the river embrochures is composed of a swampy impenetrable jungle. The large extent of unknown country included between these boundaries, is supposed to be an elevated plateau.

There is a fourth region in the African continent, not included in the above description, which comprehends the country bordering on the Red Sea, and comprises Abyssinia, Nubia, and Egypt; a great portion of the last two countries being included in the valley of the Nile. Abyssinia is composed of an elevated table-land, intersected by ranges of rocky and precipitous hills, between which are valleys of great fertility. Nubia, except on the banks of the Nile, is almost entirely occupied by deserts; the general aspect of the country being hilly, dry, and arid. Egypt consists of the narrow but fertile and alluvial valley and delta of the Nile, bounded on the east and west by low hills and desert, and on the north-east by the barren and desert tract which passes the isthmus of Suez, and stretches towards Arabia.

AGRICULTURE.

CHAPTER V.

THE CULTIVATED VEGETABLES, AND THEIR VARIETIES.

The chemical composition and physiological properties of the varieties of our cultivated vegetables, constitute one of the most important subjects connected with agriculture. Our space, however, confines us to the statement of a mere outline of them. We begin with the cereal grains, and first of them with

WHEAT.

The grain of wheat consists of two portions, the husk and the grain proper. The former, when ground, is called bran; the latter flour. The proportion of the bran to the flour is about 15 per cent. The composition of bran has been found to be—

Albuminous compounds,	19
Oleaginous do.	4½
Saccharine do.	55
Salts,	7
Water,	13
	98½

The composition of wheaten flour has been found to be something as follows:—*

Albuminous compounds,	11
Oleaginous do.	1½
Saccharine do.	76
Salts,	?
Water,	10
	98½

The salts not included in the above are as follows (decimals are omitted):—

Potash,	24
Soda,	9
Lime,	3
Magnesia,	12
Oxide of iron,	½
Phosphoric acid,	50
Sulphuric acid, and Silica,	1½
	199

Wheat straw contains about 50 per cent. of woody fibre, and the rest consists of water, starch, gum, sugar, gluten, oil, and salts. The proportion of these salts is as follows:—

Potash,	9½
Lime,	9
Magnesia,	5
Iron,	1
Phosphoric acid,	3
Sulphuric acid,	1
Silica,	70
Chlorine,	1
	99½

Of the many varieties of wheat now known, and more or less cultivated, we may mention of those usually considered most suitable for sowing in the autumn:—

a. Hunter's white wheat. For many years past, this variety has been the most extensively grown of any in the Lothians and adjoining districts. It is productive, and weighs well.

b. Uxbridge white wheat. This is very similar to the former, and its grain is the favourite one of the London millers.

c. Blood-red wheat. This is a beardless wheat, with reddish-coloured ears, and is extensively grown, being considered pro-

* This table is only an approximation, and made up of more than one analysis; and it is not to be depended upon save very generally.

lific. Red wheats, however, always bring two or three shillings less price per quarter than white ones.

d. Lammas red wheat. This is the variety of red wheat that is preferred in England. It is liable to shake when fully ripe, and hence requires cutting a day or two before it has reached that point of maturity.

VARIETIES OF WHEAT, FROM STEPHENS.

Compact eared. Bearded eared. Hunter's eared. Talavera.

Of the varieties of wheat suitable for sowing in the spring, we may mention:—

a. Talavera wheat. This is a white wheat, said to be remarkable for always producing either a very good or a very bad crop—never a medium one. It appears to be less cultivated than it used to be.

b. Lammas red wheat. This may be also used as a spring-sown wheat.

c. Fern or April wheat. This variety may be sown later than any other kind, even so late as April. It is awn, the spike is six inches long, and it is red coloured. The grain is small, flinty, and of a deep red colour. It weighs well—from 60 lbs. to 64 lbs. per bushel—and often yields five quarters to the acre. The flour is liked by the bakers. It is said to be particularly liable to suffer from smut.

d. Fenton wheat. Upon the whole, and for ordinary situations and times of sowing, this is the best spring wheat of any.

BARLEY.

The principal end for which barley is grown in this country, is in order that it may be converted into either malt liquor, or spirit. The husk forms from 10 to 18 per cent. of the weight of the grain. The composition of barley meal has been ascertained to be as follows:—

Albuminous compounds,	14
Saccharine do.	68
Oleaginous do.	2
Salts,	2
Water,	14
	100

The ash, or salts, contained in barley (and this includes those of both grain and husk) is thus composed:—

Potash,	13½
Soda,	8
Lime,	2½
Magnesia,	7½
Oxide of iron,	1½
Phosphoric acid,	39
Silica,	27
Chlorine, &c.	½
	99½

About 50 per cent. of barley straw consists of woody fibre; the rest is made up of water, albuminous compounds, saccharine ones, oleaginous ones, and so much as 7 per cent. of ash, which ash is made up of—

Potash,	6
Soda,	½
Lime,	9½
Magnesia,	3
Iron, &c.,	1
Phosphoric acid,	3
Sulphuric acid,	1½
Chlorine,	1
Silica,	7
	96½

Of the varieties of barley we may name—

a. Bere or big. This has four rows in the ear, and is distinguished by its prolific nature, extreme hardiness of constitution, and the coarseness of its sample.

b. Victoria big or bere. This is a much improved variety of the preceding, introduced by Mr. Fulton—extremely prolific, producing a moderately good sample, and deserving of more attention than it is apparently receiving.

c. Common two-rowed or English barley. This is what is known as common barley.

d. Chevalier barley. This is an improved kind of two-rowed barley, propagated by Mr. Chevalier in Yorkshire, many years ago, and considered to produce a much finer sample, particularly for malting purposes. It is about eight days longer in ripening than the common barley, and perhaps sixteen days longer than the bere.

BARLEY.

Four-rowed bere. Six-rowed bere. Two-rowed barley.

OATS.

The following is an analysis of the grain of this important cereal:—

Albuminous compounds,	20
Saccharine do.	69
Oleaginous do.	6½
Salts, &c.,	3½
	99

These salts were thus composed:—

Potash and soda,	26
Lime,	6
Magnesia,	10
Oxide of iron,	½
Phosphoric acid,	44
Sulphuric acid,	10
Silica,*	2¼
	99

Of the many varieties of the common oat, we may instance:

a. The old black oat. This is the old oat of Scotland, now rapidly disappearing.

b. The dun oat. This kind is distinguished by its dark brown grains, which hue, however, passes to a grey at the point. It is very hardy and prolific, but a little disposed to be late of ripening, and hence not so suitable for high-lying situations as it otherwise would be.

c. The Drummond oat. This is a pretty good oat, and considered of all to be the most qualified for clayey and heavy soils.

d. The Kildrummie oat. This is distinguished by its earliness, and hence is suitable for late situations.

e. The Blainslie oat. This productive oat is greatly cultivated in Berwickshire.

f. The Hopeton oat. This is a much esteemed variety. It is known by a red mark in the middle of the body of the grain. It is prolific and early, and not liable to shake or lodge; but it is considered as liable to smut, and not to succeed at all well upon heavy clays.

g. The potato oat. This is perhaps the most generally esteemed variety of any. It may be recognised by its very white and short grains. It obtained its name from having been originally found by accident in a potato field in Cumberland.

h. The Sandy oat. This is not so named because it is suited for a sandy soil, but because it was first found by a farm servant called Alexander or 'Sandy' Thomson. This oat is remarkably hardy, productive, and very regular in the ripening.

i. Tam Finlay's oat. This is a hardy, but apparently somewhat inferior, oat, but probably suited to a moist climate.

The above are the more important varieties of the oat grown in Scotland, that part of the island where this cereal is by far the most successfully cultivated.

Rye is now so little cultivated, that we may pass it over, and proceed to the leguminous plants, cultivated for the sake of their farinacious seeds and their straw, namely, beans and peas.

BEANS.

The following is one analysis of the seed of the bean:—

Albuminous compounds,		22
Saccharine do.		45
Oleaginous do.		3
Salts,		3
Water,	17	
Husk,	8	
		25
		98

* Of chlorine, a trace.

The salts of the bean seed are composed thus:—

Potash,	21
Soda,	19
Lime,	7
Magnesia,	9
Oxide of iron,	1
Phosphoric acid,	38
Sulphuric acid,	1
Chlorine,	1½
Silica,	2½
	100

The salts of bean straw are as follows:—

Potash,	53
Soda,	1½
Lime,	20
Magnesia,	6½
Phosphoric acid,	7
Sulphuric acid,	1
Chlorine,	2½
Silica,	7
Iron, &c.,	1
	99½

The following two varieties are almost the only ones used for field culture:—

a. Scotch horse bean.

b. English field bean. Of these the latter is the more prolific.

PEAS.

The following is an analysis of the grain of the pea:—

Albuminous compounds,		20
Saccharine do.		54
Oleaginous do.		2
Salts,		3
Husk,	11	
Water,	9	
		20
		99

The salts of the pea are as follows:—

Potash,	36
Soda,	7½
Lime,	5
Magnesia,	8½
Oxide of iron,	1
Phosphoric acid,	33
Sulphuric acid,	4
Chloride of sodium,	3
Silica,	½
	97½

The straw of peas contains no less than 12 per cent. of albuminous compounds. Its ash is thus composed:—

Potash,	4½
Lime,	55
Magnesia,	7
Iron, &c.,	1
Phosphoric acid,	5
Sulphuric acid,	7
Silica,	20
	99½

Although many varieties of the pea exist, two only are known in practical farming—the common grey field pea, which is prolific, but late in ripening; and the partridge, which, while it is also prolific, is earlier in coming to maturity.

The two root crops most extensively cultivated are the turnip and the potato, which now claim our attention.

THE TURNIP.

One analysis of the turnip is as follows:—

Albuminous compounds,	2½
Saccharine do.	5½
Oleaginous do.	⅕
Salts,	½
Water,	89½
	98⅕

The ash of turnips has been ascertained to be composed of:

Potash,	42
Soda,	5
Lime,	13½
Magnesia,	5
Oxide of iron, &c.,	1
Phosphoric acid,	7½
Sulphuric acid,	13½
Chlorine,	3½
Silica,	8
	99

Three kinds of turnips are cultivated—the Swedish, which keeps the longest in spring; the white, which runs earlier to maturity, and, moreover, cannot withstand the action of frost; and the yellow, which, in both respects, is intermediate between the two.

Of Swedish turnips we may mention:—

a. The purple top. This is named from the upper part of the root being of a purple, or rather, dullish-red colour. In most districts, of late years, this has been the favourite Swedish turnip.

b. The green top. The name of this is derived from the green colour of the top. It is probably in all respects equal to the former.

Of yellow turnips there are several varieties. Perhaps the most important are the three following:—

c. Aberdeenshire bullock. This is known by its green top, and is a justly esteemed kind. Another yellow turnip exactly resembles this, save in having a purple top, and is called purple-topped bullock turnip.

d. Dales hybrid. This is a yellow turnip, produced by crossing a white globe and green-topped Swede. Of all the late-keeping sorts, this comes earliest to maturity, and may therefore be sown late. It is productive.

e. Purple-topped hybrid. This is likewise a yellow turnip, produced by crossing a white globe, but with a purple-topped Swede. It resembles the previous one, but more approaches to the nature of the Swede, and therefore requires earlier sowing; but it keeps long without shooting, at the end of winter or beginning of spring.

We will mention four varieties of white turnips:—

f. The common white globe.

g. The stone globe. This grows deeper in the soil than any of the other globes, and is characterized by its stronger and darker green foliage. It is by far the hardiest of all the globes.

h. Autumn stubble. This arrives at maturity earlier than the common globe, and in very favourable situations a crop may be got in autumn after the corn has been removed. It cannot resist frost at all.

i. Tankard turnips. These are distinguished by their oblong shape. They grow a good deal out of the ground. They are the earliest of all the turnips, but they cannot endure frost.

POTATOES.

Potatoes vary very much in the proportion of their proximate principles. Perhaps, upon an average, they contain one and a half per cent. of albuminous compounds, eighteen of saccharine, a fifth of fatty ones, seventy-five or seventy-six of water, and one and a half of ash. This ash is particularly rich in potash. The whole constitution is as follows:—

Potash,	55½
Soda,	1½
Lime,	2
Magnesia,	5
Phosphoric acid,	12½
Sulphuric acid,	13½
Chlorine,	4
Silica,	4
Iron,	½
	98½

Several hundred varieties of the potato have probably existed. Of these, many have gone out of cultivation, and others have been destroyed by the potato disease. The three kinds, perhaps, most cultivated now, are the regents, the cups, and the Orkney reds.

FORAGE PLANTS.

The composition of these has been little investigated. They consist of water, albuminous compounds, saccharine ditto, a large proportion of oleaginous ones, and ash. The following table shows the analysis of some of them:—

	Meadow hay.	Clover.	Rye grass.
Potash,	18	35½	8
Soda,	1	½	2
Lime,	23	33	6½
Magnesia,	6½	8	4
Oxide of iron, &c.,	1½	½	¼
Phosphoric acid,	6	8	12½
Sulphuric acid,	2½	3	—
Chlorine,	2½	3½	—
Silica,	37	7	64½

Of late, a very valuable variety of rye grass—the Italian—has been introduced into British farming.

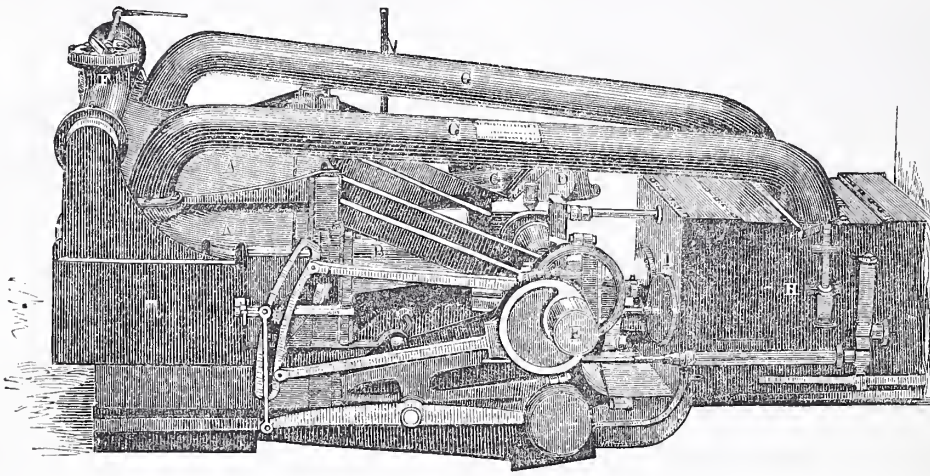
PENN'S TRUNK ENGINE,

FOR DRIVING THE SCREW-PROPELLER DIRECT, WITHOUT THE INTRODUCTION OF GEARING.

Many years have now elapsed since the introduction of a screw for the purpose of propelling ships; but its rapid extension, within the last five years, in the British navy, has induced many of the most eminent engineers more seriously to turn their attention to the best means of driving the screw-shaft, since the forms of the steam engine commonly used for the purpose of driving paddle vessels are not found to be convenient or economical for the screw ship. There are several reasons for this: first, because the propeller-shaft, in the case of the screw, lies considerably *below*, instead of *above*, the water-line, and, consequently, there is not sufficient room in the vessel to allow of the engine being placed underneath the shaft; secondly, on account of the pitch of the screw, or the length the blade would occupy upon the shaft, if the blade were extended so as to form a complete convolution, being so much less than the circumference of a paddle-wheel, as to require a greater number of revolutions in a given time; and, thirdly, in the navy it is desirable to keep the whole of the machinery below the surface of the water. In the first instance, geared engines were adopted—that is to say, the engine was driven at a slow speed, and that of the screw-shaft increased by cog-wheels of different diameters. With this description of machinery, the first and second considerations are overcome; but not so the third, as with the large cog-wheels required, the machinery reaches far above the water-line of the vessel. The next system tried was by attaching the steam engine directly to the shaft; but here another difficulty arose. The screw-shaft to be driven occupies about the centre of the cross sectional area of the displacement of the vessel, so that in many vessels there is not sufficient room for the cylinder, piston-rod, and connecting-rod, in line, either below, above, or on either side of the shaft, without so

proportioning the engine as to impair its efficiency in an economical point of view. It is principally to overcome this last difficulty that the "trunk engine" has been introduced by Mr. Penn. It derives its name from the fact of the usual piston-rod being constructed of the form of a hollow tube, or *trunk*, the piston being attached to the exterior surface of the trunk at about the middle of its length, so that the surface of the piston, which the steam acts upon, is the area of the annular ring formed between the exterior surface of the trunk and the interior surface of the cylinder; the trunk passes through both ends of the cylinder, in which it slides, steam-tight, by stuffing-boxes. The connecting-rod is attached, one end to the centre of the hollow trunk, and the opposite end to the crank of the screw-shaft, so that the whole length of the ordinary piston-rod is saved. No guides are required beyond that supplied by the trunk itself passing through both ends of the cylinder. The diameter of the hollow trunk is somewhat less than the length of the crank, to allow the connecting-rod to vibrate with the crank without touching the inner surface of the trunk.

The accompanying drawing is from a daguerreotype of a pair of engines of this construction, sent to the Great Exhibition by Messrs. Penn. The two cylinders, A, A, are placed side by side, horizontally; B is the trunk of the front engine, that of the other cylinder being hid by the framing; C the connecting-rod, D the crank, E the screw-shaft, F the steam-pipe to the cylinders, G the exhaust-pipes to the condenser, H, placed upon the



opposite side of the vessel; I, I, are the ends of the air-pumps, which are placed within the condenser; the air-pump rods are attached directly to the piston of the engine. Several objections have been raised to these engines; but practice has proved them all to be incorrect; and what might have been, at first sight, considered almost as inevitable—viz., the wearing away of the under side of the cylinders, from the great weight of the trunk and connecting-rod, is found to be compensated by the peculiar arrangement of the engine; for when the piston is moving towards the screw-shaft, the crank-pin is above the level of the shaft, and, consequently, is pulling the trunk up against the upper surface of the cylinder; and when the piston is returning, the crank, being below the level of the shaft, is pushing it upwards in like manner, so that the weight of the trunk is partially carried up the crank-pin. Some idea may be formed of the estimation of these engines by the Admiralty, from the following list of ships of war which have been, or are in the course of being, fitted with the "trunk engines," since their first introduction by Mr. Penn in the *Arrogant*:—

VESSELS FITTED, OR FITTING, WITH THE TRUNK ENGINES, BY JOHN PENN AND SON, GREENWICH.

ROYAL NAVY.

	Horse Power.	Guns.
Arrogant,..........	360	50
Agamemnon,.......	600	91
Cæsar,...............	400	90
Euryalus,...........	400	50
Encounter,.........	360	12
Imperieuse,........	360	50
Royal Albert,......	400	120
Royal George,......	400	120
St. Jean D'Acre,...	600	91

REVENUE SERVICE.

	Horse Power.	Guns.
Sea-Mew,..........	60	6
Argus,..............	60	6

RUSSIAN GOVERNMENT.

	Horse Power.	Guns.
Paltuan,...........	360	50
Argonaut,.........	60	6

PERUVIAN GOVERNMENT.

	Horse Power.	Guns.
Amazonas,.........	300	30

BRAZILIAN GOVERNMENT.

Two vessels of 70 horse power each.

PENINSULAR AND ORIENTAL COMPANY.

Himalaya, 700 horse power.

CRYSTALLIZED GOLD FROM CALIFORNIA.

All metals have their original crystalline forms; and in a recent number of Silliman's American Journal, several interesting specimens of crystallized gold from California are described by Mr. Francis Alger, of Boston. The paper was read before the Boston Society of Natural History; and some of the points to which the writer adverts are well worthy of attention. The collections in which the specimens were found were brought home from California by Mr. G. E. Tyler, of Boston, and Mr. H. B. Platt, of New York. The crystals were distinctly octahedral, simple and modified, the surfaces being but slightly disfigured by attrition, or the effects of transported action—a very unusual circumstance, as gold is generally found in comparatively minute grains, at a distance from the rocky matrix in which they were primarily embedded. Mr. Alger says, that he had never before seen what was unquestionably a genuine crystal from this new land of gold. "An irregular crystalline plane," he adds, "could only occasionally be traced out in former specimens; but here we have examples of crystallization as perfect, among the small ones especially, as are to be seen in magnetic iron ore, or in spinelle."

Of the larger specimens in these collections, the most striking examples were three octahedrons (or eight-sided figures), of the sizes exhibited in the annexed cuts. Each of these crystals was found in an isolated state. The smallest one

(fig. 1) is the most perfect, and is so entirely free from any adhering portion of the matrix to which it must have been attached, as to lead Mr. Alger to a very important conclusion, namely, that this matrix was a much softer material than the quartz, in connection with which the gold is usually found.

Fig. 1.

Fig. 2.

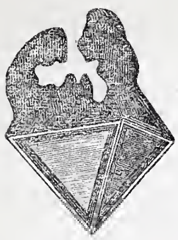
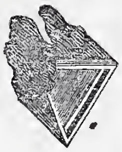


Fig. 3.



He thinks, also, from its slightly worn appearance, that it had been but recently dislodged from its original place of deposit. If not quartz, it would have been exceedingly interesting to know the material of the matrix; but the reason assigned by Mr. Alger for believing it not to have been quartz, appears to us very far from conclusive. This unusually perfect crystal exhibits, as partly shown in the figure, four pretty regular faces in the upper half, and three of its six solid angles are perfectly formed to a point. Two of its faces are sunk or depressed; and in one of them the cavity thus formed is very deep and regular, like an interior triangle, the depression extending not quite to the edges, but so as to leave all round a narrow ridge, or border, the interior sides of which are parallel with the edges themselves. Mr. Alger naturally infers that this depression, which is shown by a darker shade in the figure, had been formed when the crystal was in a liquid state, and that, soon after the outside had congealed, the inner portion, or a part of it, had run out, leaving the surrounding consolidated edge in a perfect form. "I have seen," he says, "something similar to this formed among artificial crystals; as, for instance, metallic lead (which takes the form of an octahedron), and lead ore partially desulphurized, when the metal was allowed to flow off slowly just as the outer crust had formed over the surface of the crystals." This parallel case we believe to be of frequent occurrence in the crystallization of ductile metals.

In the largest (fig. 2) of the three crystals, of which the annexed sketches are given, it will be observed that only one-half of the octahedron is formed, its base blending with the rough gold, or showing only the commencement of the planes of the lower pyramid. Three of the planes are quite smooth, except along their edges, which are prominently marked by the same projecting border, or ridge, described on the smaller crystal. The depression, however, arising from whatever cause, is not so great as in the latter. This peculiarity, Mr. Alger remarks, is confined to the unmodified crystals.

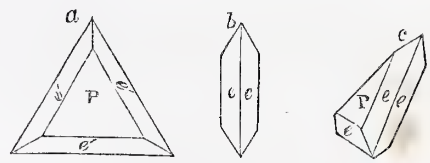
In some there is a double series of these ridges, the inner one appearing to exhibit the commencement of another crystalline face within the cavity of the larger one. This phenomenon was strikingly shown in a crystal, of which the third figure is a sketch, represented of the natural size.

The two larger crystals (figs. 2 and 3) were obtained from the beautiful collection of Mr. Platt, who resided a couple of years at San Francisco; and being in a situation which brought him into constant intercourse with persons returning from the mines, united with a prosperous business an enlightened taste for science, and purchased, at no small expense, the most interesting specimens he could obtain. His collection is described by Mr. Alger as of singular beauty and value, comprising a great variety of ramified, arborescent, dendritic, and other imitative forms, all of them sometimes fantastically joined together in the same specimen. This gentleman, says Mr. Alger, in obtaining his valuable collection, had examined gold to the amount of more than four millions of dollars.

The remarkable size of the two crystals in Mr. Platt's collection, which we have just described, and the fact that some of the other crystals contained portions of oxide of iron, induced a suspicion that the greater part of them were pseudomorphs of sulphuret of iron; but Mr. Alger believes that they were formed under the ordinary circumstances of crystallization, either in an open space, or while surrounded by a matrix, in such a fluid state as to allow them full freedom to take the form it was intended they should take. If the crystals had been cubes, he admits there might be some reason for regarding them as pseudomorphs of iron pyrites, the cube being the common form of pyrites. "But," he says, "we may well ask who has ever seen a cubic pseudomorph of gold? Crystals of gold are rare, cubes particularly so, and yet this form, on account of its simplicity, is made the primary form; whereas it would seem as reasonable, in cases of the regular system, to select that form as the primary which is most commonly and perfectly presented by the mineral, provided there is no cleavage to guide us in the determination; and there does not appear to be any, well made out, among most of the native metals. By assuming those which most commonly occur in nature, we seem to recognise a sort of inherent disposition—a preference, as it were—which is shown by the mineral itself; and we avoid what seems to be a palpable inconsistency, namely, the establishing of a cube as the primary form of minerals which have never been known to occur under such form, and which even present a distinct octahedral cleavage." This reasoning, if not perfectly conclusive, affords a pretty satisfactory presumption in favour of the octahedron as the primary form of gold; and if this were more generally known, much disappointment and trouble might be saved, in cases where sulphuret of iron and other crystalline metallic forms are mistaken for the precious ore.

Several rare modifications were found by Mr. Alger in Mr. Tyler's collection, some of them resembling those which come in their most perfect forms from Brazil. Figures of two of these are annexed—one represented by fig. 4, ($a, b, c,$) exhibit-

Fig. 4.



ing a compound form, produced by the union of two opposite segments of an emarginated octahedron; the other (fig. 5) is a modification of the same form, though apparently consisting of irregular six-sided tables, with truncated edges. Some of the unmodified macles, as shown in different positions by fig. 4, ($a, b, c,$) are stated by Mr. Alger to be very distinctly formed, the edges between $e\,e$, uniting the two segments of the octahedron, being well defined. This is very strikingly shown in the lowest of the group, represented by fig. 6, in which the crystals are exhibited as magnified to twice their natural size. Fig. 7 shows the opposite side of the same specimen, connected

Fig. 5.

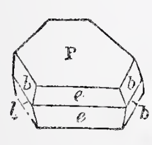


Fig 6.

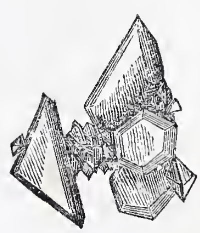
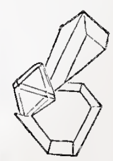


Fig. 7.

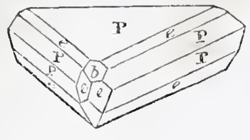


with two other crystals, one a very beautiful and smooth planed octahedron, with emarginated edges.

Fig. 8 exhibits a macle of gold, which came from Malto-Grosso, in Brazil, and is in the collection of the School of Menes, Paris. It is similar to that represented in fig. 4, from which

it only differs in exhibiting more of the planes of the octahedron and dodecahedron. Our figure is copied from the volume of crystallographic illustrations accompanying M. Dufrénoy's treatise; but besides conforming his lettering to the notation of Phillips, we have made primary planes of those which are given by Dufrénoy only as secondaries of the cube.

Fig. 8.



In all these the octahedral (or eight-sided) form is manifest, which may, therefore, be assumed to be the form natural to gold, when its particles crystallize in cooling. But Mr. Alger remarks, in conclusion, that "as nearly all of these crystals show the effects of more or less abraded action, it is often difficult to distinguish planes confined within such narrow limits, and which are too small or too rough to admit of accurate admeasurement. We can hardly expect," he continues, "to see many perfect crystals from California, until the rocks themselves are systematically explored, from whence have proceeded the millions of fragments that are now scattered over the plains and valleys. We may then, from the indications already afforded, look for crystals of gigantic dimensions, and possessing all their native unaltered beauty."

The vast and prolific fields of gold which have now been discovered in Australia, and which have already been explored with such unparalleled success, lead us to hope that much interesting additional light will be thrown on the natural history and primitive developments of this precious metal. It has hitherto been found so abundant on the surface, or mixed in minute grains with the soft soil, to which it has been washed from its rocky matrix by the winter torrents, that comparatively little of the secrets of its ancient history have yet been ascertained or revealed. It is to be presumed, however, that it does not altogether lie on the surface, like common alluvial deposits; and that, in all probability, the time is not distant when we may anticipate, with Mr. Alger, its excavation from the solid rock in masses and forms which, while enriching the finder, will constitute an equally precious treasure in the eyes of the mineralogist.

THE IMPORTANCE OF GEOLOGICAL STUDIES,

IN CONNECTION WITH THE PRACTICE OF ARCHITECTURE.

By George Wilkinson, Esq.

Most persons are more or less interested in the construction of their habitations, and all see the advantages of public structures, and appreciate the importance of bridges, canals, and other public and private buildings, and probably see in them the progress of civilization, and the benefit and dignity they confer on a country; but few, and very few, know anything of the materials employed in their construction, which too often present themselves to their minds only as a heap of stones and mortar. If we look to the early history of the most ancient nations, we find that the art of building has attended the first advance of civilization; and the use of worked stone has succeeded to caves in rocks, and the rude wicker or earth work of their common and early structures; but the conversion of stone to the increasing artificial wants of society was necessarily consequent on the advance of the mechanical arts before it could be shaped and applied. How interesting are the first though rude efforts displaying practical geology! The bold and noble monuments of the early ages show the natural vigour of the human mind, untutored in the mechanical skill and art of later times. The stupendous monolithal structures, and those early sepulchral monuments, known as cromlechs, cairns, and moats, which abound throughout Western Europe, were doubtless the work of a people who, taking nature for their guide, by prodigious labour, raised and put together, and frequently conveyed to great distances, for the erection of their monuments, the immense stones which, detached from their native beds, were distributed over the surface of the country. Most of those stones are of the primary and crystalline class of rocks, which, from their hardness, have resisted the violence of that disturbing power which removed them from their mass, and afford us a good knowledge of their enduring quality. Moreover, the originality and boldness of their application, resulted from minds familiar with nature's works and untaught in the arts which, in after ages, accomplished by skill and the use of smaller sized materials, what the earlier ages, unskilled in building, could alone express by the magnitude of the stones.

Let us consider the more advanced history of the principal nations of the earth, and we shall find that geology,—which term I may here use to express the converted rocks,—has received great consideration. The architects and sculptors of Greece and Rome knew the qualities of their materials; and, if we may judge from ancient writers and existing remains, gave considerable attention to them, abounding as those countries did in good materials. In the writings of Vitruvius on Roman architecture, the most particular rules are laid down with regard to the selection and use of building stones, and the cements employed with them. How important are the results of their influence on society! If Egypt, Greece, and Rome, had had their principal structures of a perishable material, what would we not have lost? What interest would we now feel in those countries; or how could we have derived the great advantages which have flowed from them? Good materials, and a right knowledge in using them, have, however, produced a different result; and again, what do not those countries owe to the durability of their structures, conceived, as they have been, in a noble spirit? Without them, Rome of the present day would be unvisited by the countless thousands whose wealth now enriches her; without her buildings the classic shores of Greece would have less of European sympathy; nor would the dusky inhabitants of Egypt occupy such interesting ground but for the remains of the stupendous and imperishable monuments of her past history. Our own kingdom also possesses proud memorials in the enduring monuments of her past history—in numerous splendid ecclesiastical structures, and the other venerable records of the middle ages. Those connecting links with the past and present, afford us noble examples of the religious zeal and skill of our forefathers; whilst the perseverance which has been displayed in accomplishing their erection, is much calculated to stimulate us to bold designs. These indelible landmarks of his early home, the traveller finds deeply implanted in his mind, and it is difficult for us to estimate their effect on society, in the attachment they cause to our laws and institutions. Nor do those venerated and bold structures fail to excite a powerful feeling in the inhabitants of the new world, who, though born in a distant land, contemplate with pride and fervent admiration the works of their progenitors. But the edifices of centuries past, many of which, even in their dismantled state, have withstood the destructive violence of the elements, will yet outlive very many of the most costly structures of the present day; and until a very recent period, so comparatively few were the buildings calculated to endure to any distant period, that future ages, judging by our public structures, will look upon the people of the present time as a degenerated race, and in the erections of centuries back will contemplate the finest and most durable monuments of architectural skill.

Many persons may say that a durability sufficient for the age is all that is necessary, and that posterity, which has done nothing for them, may act for itself. This, however, even in a narrow practical and economic point of view is most erroneous, for the constructive arrangement of the ancient buildings is less costly than in those of the modern period, and from their simplicity and the right use of the materials employed, they are more sound and durable edifices. In the buildings of the present day the simplicity of early structures has been lost sight of; a laboured mass of cut stone being more appreciated by the public than outline of design, and harmony of effect. We see in the ancient structures a homogeneous construction—the use of timber as supports under masonry is avoided; where openings or projections occur, stone arches or other stone supports are employed, and a much more general use of stone, for various purposes, prevails, than at the present day; and in them we have models of constructive arrangement which we may profitably imitate. Many of the old buildings are so constructed that when dismantled of their roofs and their floors, they return almost to the state of the original rock, perhaps as a mass of limestone, for the stones may be lime, the sand may be that of limestone, and the lime burnt from the same rock. Such is frequently the case; thus, the mortar being good, becomes hardened by age, and more approaches the nature of stone; for it is said by an intelligent and scientific Frenchman, who has given much atten-

tion to cements, that it requires 1000 years to make mortar really good. Without doubting that a few years are sufficient to produce good mortar, it might be stated that the mortar of the Egyptian Pyramids, now supposed to be nearly 4000 years old, is still in a good state of preservation. Structures so constructed become like a solid mass of rock; and that this is the case, the explosions made by Cromwell, in the 17th century, have very well shown, for the remains of some of the old castles, of which portions have been disturbed, appear almost imperishable. The sound and enduring state of some of the ruins, the original forms of which are still perfect, enable us fairly to state that a right use of the rocks of the earth has been capable of producing such a solid mass, that many may now, in their skeleton shapes, fairly be called architectural fossils; and they afford to the practical, as organic remains do to the scientific geologist, valuable studies in determining the character of the rocks to which they belong.

To the antiquarian, also, the study of geology affords much information, for the use of certain rocks, and the mode of working them, determine, to a considerable extent, the chronological date of the building in which they occur. It was a peculiar custom of the Normans and Anglo-Normans, to make use of none but the sandstones or oolites, similar to those with which they had become familiar in their own country, and in the round towers, and early ecclesiastical structures, erected under the influence of the Christians familiar with the Norman or Lombardic architecture, we rarely find anything but sandstones employed in the dressed masonry. With the Normans or Lombards (under which name I may include the northern nations who established themselves on the decline of the Roman power, and perfected from the last and worst models of the eastern and western Roman empires that peculiar architecture known to us as Norman, in which circular arches are the peculiar characteristic), it was the practice to make their doorways the most enriched portions of their structures, and from being more elaborated or worked than any other part, they are commonly executed in a different kind of material, sandstones of variable quality having been generally used; and it is a peculiar fact, that an instance in which limestone occurs for dressed work or for doorways is very rare. Being familiar with the kind of materials employed in most of these structures, I do not recollect one in which the ordinary limestone rock has been so used.

It is not until a late period of the Norman architecture in Ireland that limestone has been employed. In the large limestone tract of the west of Galway and Mayo, (in Ireland,) where are the ruins of Cong and Ballintubber, in the later Norman and transition styles of architecture, a light coloured easy-working limestone has been obtained from some distance; while the limestone of the locality, which is now preferred to any other material, and is conveyed to distant places for use, has been avoided excepting for the erection of the unwrought faces of the common walls. After the period in which these buildings were erected, limestone appears gradually to have come into general use in all parts, and now the directly opposite custom prevails, limestone being commonly used in sandstone districts; and I have known masons when employed in working sandstone to which they have been unaccustomed, to complain of stiffness and swelling of the arms for some days occasioned by the toughness of the stone, so different to the brittle rebounding effect of the limestone. It is most probable that the brittle nature of the limestone, in the working of which the Normans were not skilled, rendering it difficult to shape into mouldings after the masonry was built, as was commonly their custom, may have operated against its use. Those interesting structures, the round towers, on which so much that is evidently erroneous has been written, appear from their architectural and constructive peculiarities to be decidedly after the early Norman style of architecture. These edifices, of which Ireland has just reason to be proud, display to the practical geologist most interesting models of simple constructive arrangement, erected as they are with various kinds of rocks, including granite, slate, sandstone, and limestone, and which are almost always the stones of the locality, excepting in the superior dressed work of the doorways. Many antiquarian works of a recent period, show very mistaken ideas as to the nature of the materials with which these early buildings have been constructed, and, therefore, draw erroneous conclusions. A very slight acquaintance with practical geology tends to correct such errors; and it is most likely that such statements as those of Colonel Morris, in his work on the round towers, (in which he determines the red sandstone of some of these structures in the south to be Roman brick, and deduces from this certain conclusions regarding their origin,) will not be repeated.

There is one more feature, connected with antiquarian research, upon which I would wish to remark, viz., the peculiarity of some of the earliest Norman architecture of this country. The architecture of the Normans in every country in which it was introduced (though preserving all the general characteristics of its early originals,) differs in details. It clearly continued to be the style of architecture in Ireland much later than in England, and extended over a much longer period than in other countries, owing, doubtless, to the peculiar and remote position of Ireland, at the western limits of Europe. It also frequently differs considerably from the Norman architecture of England; but it is in the early examples that the most distinctive details occur; and here a peculiarity is devolved, for which practical geology affords a ready and satisfactory reason, for the very hard nature of the stone has induced a different kind of ornament, and in several of the early examples we find the most elaborate execution on almost square columns, or rather jambs and architraves, quite at variance with the bold and deep cuttings so common in the Norman style. Nor is such a result other than should be expected, for they must have been deprived in those early ages of the facility of obtaining softer stones. It was the practice of the Normans at an early period to supply stones even to England, where soft oolitic stones abounded in many parts; and when at a later period intercourse with Ireland improved, we find that the stones of Normandy were brought to this country, and are to be met with in many of the ecclesiastical buildings, more particularly on the eastern coast.

Owing to the neglect of the study of geology, designs are often prepared by architects and engineers, to whom is intrusted the expenditure of very considerable sums, without sufficient regard to the resources of the locality, the inquiry being confined to the question of cost, as to the nearest place from whence materials required to carry out a particular design may be obtained. It has frequently happened that stone has been brought from a great distance at considerable expense, when rocks of an equal, or of superior quality abound in the vicinity, with regard to which an acquaintance with this science might have reasonably afforded information. Numerous instances of such occurrences have come under my own observation within these last few years, where, either from sinking wells, or in making excavations of other kinds, or by chance trials for stones, there have been unexpectedly discovered, at a very great advantage in outlay and frequent benefit to contractors, some very valuable quarries; in illustration of which I may mention a particular instance with which I am familiar, in the discovery of a valuable working limestone quarry in the vicinity of a nobleman's mansion, which, if earlier known would, I am informed by the contractor, have saved him upwards of £1000 in the expense of procuring stones, which he had to convey a distance of many miles, and which were of an inferior quality to those which could have been obtained on the spot. If the science of geology were made practically useful, such occurrences would be rare, and in time would be altogether avoided.

The professional man is often deterred from the study of geology by the difficulty of mastering the technicalities, if I may so term them, of the science; and the theoretical geologist, on the other hand, is unable to appreciate the wants of the other; but acting together, the result would be mutually beneficial. The practical man would acquire the theory of the science with much greater facility; the theoretical geologist defining the geographical outline of the principal rock formations, and by the existence of fossils, and by recorded facts, determining where similar formations may or may not be expected to prevail; the professional member would obtain specimens of the different stones for experiment and chemical analysis, which in the yet imperfect state of geological science would most probably induce new theories in regard to many rocks, where the gradation from one mineral character to another is almost imperceptible. The peculiar stratification or dividing joints of the rocks are also features for profitable investigation. If we examine the various kinds, we find great differences to exist in the size and shape of the masses into which they are subdivided; and in the same kinds of rocks we discover a subdivision peculiar to certain

depths or other influences. In all, however, we recognise the wonderful contrivance of the Almighty in adapting the surface rocks of the earth to the wants of industrious man. The greater portion of these rocks (the result of sedimentary deposition in water, of which the traces are still evident) occur in layers or thin beds, so separated from each other as to admit of being easily raised; others, with beds of soft clay, or other matter interposed; and, in the rocks of the primary or igneous classes, among which are included granites, basalt, &c., and which, occurring in large masses, would otherwise frequently be unconvertible, we observe the wise provision of nature in traversing them with joints or cleavages influenced by some prevailing law of crystallization or polarization, not as yet, perhaps, sufficiently accounted for. In the more solid masses, in which are included some of the limestone as well as other rocks, from the effect of internal heat, great pressure and other causes, the stratified form has disappeared; while the same cause which has obliterated the earlier divisions has itself produced others; and in some instances so shattered is the upper portion of the rocks that the practical builder altogether avoids them, although the removal of some feet from the surface would frequently disclose a most valuable material. Hence the advantage of scientific investigation and recorded facts. At the present time the want of a society combining practical and theoretical inquiries cannot, I think, but be manifest to all who contemplate the ordinary edifices of the present day. A better acquaintance with geology, or what is the same thing, a better knowledge of the rocks of the country, is essential to the production of edifices which will vie with those of past ages in durability, and harmonious adaptation of design to the locality. And it is, I conceive, only by correcting the public mind, and by giving assurance from experimental results and established facts, that a beneficial change can be effected.

Nor is the pursuit of this science unimportant as regards the *commerce* of the country. Let us look to the article of slates. At the present time there are several good quarries working, among which I may mention Killaloe, Valentia, and one more recently opened with great spirit by Mr Synge in the county of Wicklow (the slates from which resemble those from the Bangor quarries); yet, such is the state of public opinion with regard to the Irish slates as to preclude their general use; and because at one period, in their early working, the slates of this country were very inferior to those now produced, the prejudice arose, and still continues, and no effort has been made to show by experimental inquiry, that Ireland contains slate quarries more than sufficient to supply all her wants; and yet thousands of pounds are annually going out of the country *in a direction from which there is no reciprocal trade.* I feel persuaded that it only requires the assurance which would result from well-directed efforts of the Geological Society to cause, in a very short period, the annual expenditure of several thousands of pounds in the country in raising a native material, by extending the use of it, which money now unnecessarily goes to Wales; and there is this circumstance attending an increased demand, that the quality and economy of raising the slates will be improved. I may speak from experience on this subject, having used native slates in many instances; but from the little encouragement given, and from the prejudice still remaining, though the cause is chiefly gone, the proprietors have to struggle with many disadvantages in effecting a sale against their long established competitors who have a trade in the Welsh slates. In more than one instance the native slates have been partly placed on buildings, in which I was concerned; and, to satisfy prejudiced objections, it was expedient to have them removed, although the same slates have been used elsewhere. At Killaloe, where a few years back there was a rude surfaced mountain on which only goats or very poor cattle browsed, there are now, owing to the slate rock which prevails there, many hundred men daily employed. At Valentia not less than 200 are in daily work, and probably half that number at Mr Synge's in Wicklow. The importance of the encouragement of such a trade is therefore manifest; for a regular trade of this kind, with all its minor ramifications, is much more beneficial to a country than the mere temporary employment on public works, which, creating a temporary excitement, occasionally works more mischief in the end than otherwise. At present, the proprietor of the Valentia quarries, who works them chiefly for sawn flags, finds his principal market in London, while articles of this kind required for Ireland are obtained out of the country.

A similar remark may be made with regard to bricks. Good clay is abundant in Ireland, and good bricks are made in some parts, and might be made in many others; but from the frequent indifference as to the purchase of good materials, there is, in many cases, great carelessness in their manufacture. If, however, samples of bricks, and particulars of the clay, were collected, and the result of experiments made known, the good articles would be encouraged, and the making of many of the perishable ones of the present day, which are dear at the cost of carriage, would greatly decrease, and the buildings of the country would thereby be improved. Again, there is a strong prejudice against Irish bricks, which are really good. In illustration of this, I may mention a case connected with the manufacture of fire bricks at Dungannon, which are of excellent quality, and remarkably well made from the clay of the coal district, like those of Staffordshire; but the public, not knowing if they were really good, prefer buying the English fire-brick. Their sale is, however, now, or was, some little time since, considerable; but it arose from an ingenious, and scarcely to be condemned trick of the maker, who stamped the word Stourbridge on his bricks, and they then had a ready sale as good Staffordshire brick.

Without entering into details, I would beg to advert to the important light in which the study of practical or economic geology, is now viewed by the government, in confirmation of the remarks which I have made. Previously to the building of the new houses of parliament, a commission consisting of geologists (accompanied by the architect of the building) was appointed to investigate the various qualities of the different convertible building stones of the country. The result of their experiments has now been published in the parliamentary papers, and has been received with the greatest satisfaction. It has also had the important effect of originating a museum of economic geology, for displaying the properties of the different stones of the country, in order that practical information on the various materials, with the characters which experiment and observation of the present state of those materials used in ancient structures supply, may prevent the continuance of the very numerous failures which have attended the use of many stones employed in different parts of the country, and which, being of inferior quality, have brought to speedy ruin many noble and interesting buildings. The institution referred to is supported at the expense of the government, and is under the direction of the most distinguished geologists of the day: connected therewith is a curator, and a laboratory for an analytical chemist, by whom experiments are made on various rocks, and who affords, at a fixed charge any information required relative to the various properties of rocks for building, mining, or agricultural operations. I recently had an opportunity of visiting this museum, but found less really useful information for the architect and practical builder than I expected. It, however, contains most valuable and interesting collections of models, illustrative of the strata of the earth, the working of mines, and the minerals themselves in their several progressive stages from the mine to the manufactured article. From the constitution of the institution, with all its admirable features, it does not appear to me to represent the spirit of a department in which the minds of those most interested in building operations are engaged; and from the contrary opinion with reference to the Dublin Geological Society, combining as it does, scientific and practical geologists under its most intelligent and zealous curator, I augur that with perseverance most useful and interesting results will flow from their labours.

Reverting to the more practical consideration of the subject, we find that the altered circumstances in the advanced civilization of the present age, now occasion the much greater use of the more convertible building stones; and so variable are the different kinds of rocks in the degrees of hardness and facility of conversion, in their colour and their relative durability, that a knowledge of these properties is now almost indispensable to the economical erection of the structures of the present day, as well as for the designing any building, in which the bold simplicity and spirit of the ancient structures is to be embodied; and hence the value of experiments and recorded observation on the defective materials which ancient and more modern buildings present, and without which expensive practical experience, and fre-

quent failures will alone teach. The importance of attention to the good quality of the building stones will be evident by reference to buildings in Dublin, and to the already decaying nature of much of the granite in the Four Courts, and portions of many other structures; and I may mention that it is but a few years since the necessity arose for restoring with new masonry the walls of the extensive building of Trinity College Library, and the walls of the cathedral structures of Christ Church and St. Patrick, in the old buttresses of which latter buildirgs the effects of perishable stone may now be seen.

CHEMISTRY OF ORGANIC NATURE.

CHAPTER III.

THE ANIMAL KINGDOM.

OF THE PROXIMATE PRINCIPLES FROM WHICH ANIMALS ARE DERIVED.

A CAREFUL study of the composition of animals, and of the food which nourishes them, has led to the conclusion, that the proximate constituents of animals exist, ready formed in the substances which serve as their aliment. By the proximate constituents we mean, those complicated bodies found in animals, such as *fat*, *muscle*, &c. which are compounded of the *ultimate* elements, carbon, hydrogen, oxygen, and nitrogen or azote. This view was first suggested many years ago by Dr Prout, and has been generally adopted in this country. His conclusions were derived from a careful examination of the food supplied by nature to a large division of animated beings, and he inferred that milk constitutes the type of the food for animals.

1. The greater portion of animals consists of the elements of water; and in milk, we possess this fluid in abundance. Water not only assists, by the liquid currents to which it gives rise in the various vessels of animals, in conveying the solid particles of the blood or digested food from one part of the body to another, but it constitutes the greater proportion of what appears to the eye of a solid and permanent nature. It is stated that a perfectly dry mummy at Gottingen, of an adult Guanche—preserved with all the muscles and viscera entire, only weighed seven pounds and a-half; although its weight might have originally amounted to perhaps from 100 to 144 lbs.

2. The milk also contains *sugar*. And in all the food employed by animals, the principal constituent is starch, which is easily convertible into sugar, and differs from the latter body, by containing the elements of water less.

3. Milk likewise contains an albuminous principle *casein* or curd of milk, possessing the same composition with the albumen which we find dissolved in the liquid portion of the blood. We may therefore reasonably conclude that, in sucking infants, the curd of milk supplies the blood with its albumen. The curd of milk has been found identical in its composition with the *fibrin* of the muscles of animals, and hence in young infants we ascribe the origin of the fibrin to the curd of the milk, which serves as their food.

4. Milk contains butter, an oil, one of a class of bodies which seem to act an important part in the animal economy. We draw this conclusion from its presence in most of the tissues, and from the influence which it seems to possess in supporting animal life when other aliments are withheld.

The whole of these compounds, with the exception of sugar, "are identical," says Dr Prout, "in their essential characters with the materials composing the frame of the animals themselves." Owing to this identity many animals are saved the labour of forming these proximate principles from their elements, and have only to re-arrange them as their exigencies may require. The task of forming the proximate principles is thus left to the inferior animals or to plants, which are endowed with the capacity of compounding these proximate principles from matters still lower in the scale of organization than the animals and plants themselves. That this observation holds good throughout the whole system of dietetics is sufficiently obvious when the subject is examined with due attention.

Bread constitutes everywhere the staff of life, and we now apply to its consideration with a due reference to the preceding principles.

The first chemist who examined flour with any successful result was Beccaria, of Bologna, in Italy, and he detailed his experiments in a communication to the society of that place in 1742. In the abstract of his paper, it is observed, "to endeavour to know the nature of our food is to satisfy the obligation which the oracle of Apollo imposes on every one, to know one's self, for if we except the spiritual and immortal part of our being, and if we only take into consideration our bodies, is it not true that we are composed of the same substances which serve as our nourishment." "It is with reason that the Greeks, Romans, Arabians, and lastly, the French and Italians who have followed so gloriously their footsteps, have applied themselves to the explanation of the properties of food." Impressed with such ideas, Beccaria undertook the examination of the flour of wheat, which is so extensively employed by mankind as the staple article of food. He found that by washing flour, moderately fine, to prevent it passing through the searce, it could be divided into two parts, a glutinous part and a starchy portion. The characters of these two bodies are quite distinct, he says; and are well observed by digesting or distilling them. These principles, thus analyzed, appear to come not from one and the same substance, but from two very different substances. The starchy part follows the nature of the mixture from which it is derived. and affords principles similar to those of all vegetables; the glutinous part on the contrary appears to disavow its origin, and the principles which are extracted from it are the same as those peculiar to animals." He then enters into a lengthened detail of the properties of vegetable and animal bodies, and supports his first affirmation with great sagacity.

ANALYSIS OF FLOUR.

As bread is capable of itself sustaining animal life, the analysis of flour constitutes a most interesting study, for by ascertaining its composition we determine the elements of animal existence, and it is a fact of no small importance to state that recent inquiry has shown, that the elementary constituents of the blood, and tissues of the body, exist in perfect integrity in the bread employed so extensively as human food.

When we digest flour in water, and press it in a cloth, a milky fluid passes through, which, on being allowed to settle, deposits a quantity of flour. If we filter this solution it is clear, and has a sweet taste. We have thus divided the flour into three parts, 1st, starch; 2d, a solution; and 3d, an adhesive substance remaining on the cloth, in common language, called gluten. The starch possesses the components already described, and may be separated by the same process. If we boil the solution which floats over it, we observe flocks speedily making their appearance. These are albumen, and have been coagulated by the heat. If we filter this liquid and evaporate to dryness, we obtain a quantity of sugar which is also an essential constituent of flour, and may be purified by solution in alcohol. It has the same composition as glucose or grape sugar.

The adhesive matter, remaining on the cloth is to be well washed with water in order to remove all the starch; alcohol is then to be boiled on it and filtered. There remains undissolved a substance identical in composition with the fibrin of the blood and of the muscles. To obtain it perfectly pure it should be boiled first in weak, then in strong alcohol, then in ether. The ether is then to be displaced with concentrated alcohol; then weak alcohol is to be dissolved on it, and finally water; it is then reduced to a fine powder and dried

at 280°. The alcoholic solution deposits, on cooling, flakes, which are identical in composition with *casein* or the curd of milk, and with a body also which separates from alcohol. When the latter is boiled with the coagulum of human blood, from the alcoholic solution, after the separation of the *casein* by evaporation, we obtain a substance which is mixed with much fat which may be removed by ether; the residue is •Gluten, consisting of

Carbon,	53·3
Hydrogen,	7·2
Oxygen,	25·94
Nitrogen,	15·96
	100

It has usually been the custom to estimate the nutritive power of flour, by ascertaining the amount of adhesive matter remaining on the cloth when the starch is washed away. But as we have found the albumen to be soluble, it is quite clear that this important constituent will be altogether overlooked by such a process. When we examine all the constituents of flour, viz.

Starch, sugar, fat, albumen, gluten, fibrin, casein, gum, we find that the three first contain no azote, while all the others are supplied with this element; and it is well known that the fibrin and albumen of animals contain azote. These bodies are, therefore, supposed to supply animals with the constituents of blood and also of muscle; while starch, sugar, and fat are only useful in respiration. It is obvious, therefore, that the test of the nutritive power of flour and other kinds of food will be the amount of azote which they contain; and it affords us an interesting comparison of the relative value of different kinds of flour. In the following table the azote was determined by bringing the body in contact with soda and lime, and condensing the ammonia thereby formed with muriatic acid. The mean of the analysis of Dumas gives 16 per cent. for the amount of azote in the azotised constituents of flour. If we, therefore, determine the quantity of azote in flour, we can readily calculate the amount of albumen, fibrin, casein, and gluten in any particular specimen.

	Azotized principles per cent.	Equivalents.
Naumburg Bread,	16·49	100
Dresden ,,	14·30	115·31
Berlin ,,	14·21	116·04
Canada Flour,	13·81	117·23
Essex ,,	13·59	121·33
Glasgow unfermented Bread,	13·39	123·15
Lothian Flour,	12·30	134·06
United States Flour,	11·37	145·03
Do. by mechanical analysis,	10·99	150·00

In peas we find an analogous body—*Legumin*—which contains much more azote, and less carbon. This substance is the same as the emulsion in sweet almonds—produced by digesting in water, and precipitated by acetic acid.

Knowing the composition of flour, then, it is an object of interest to study the nature of fermented and unfermented bread. The vulgar idea which yielded the palm of superiority to the former, did not appear to be based on solid data; and it seems desirable that, in a case of so much importance in domestic economy, the arguments in favour of such an opinion should be subjected to a careful experimental examination. Judging *a priori*, it does not seem evident that flour should become more wholesome by the destruction of one of its important elements; or that the vesicular condition, engendered by the evolution of carbonic acid from that source, should at once convert dough (if it were unwholesome) into wholesome bread. When a piece of dough is taken in the hand, being adhesive and closely pressed together, it feels heavy; and if swallowed in the raw condition, it would prove indigestible to the majority of individuals. This would occur from its compact nature, and from the absence of that disintegration of its particles which is the primary step in digestion. But if the same dough were subjected to the elevated heat of a baker's oven (450° F.), its relation to the digestive powers of the stomach would be changed; because the water, to which it owed its tenacity, would be expelled, and the only obstacle to its complete division, and consequent subserviency to the solvent powers of the animal system, would be removed. This view of the case is fully borne out by a reference to the form in which the flour of the various species of *cerealia* is employed as an article of food by different nations. By the peasantry of Scotland, barley-bread, oat cakes, peas-bread, or a mixture of peas and barley bread, and also potatoe-bread mixed with flour, are all very generally employed in an unfermented form, with an effect the reverse of injurious to health. With such an experience under our daily observation, it seems almost unnecessary to remark, that the Jew does not labour under indigestion, when he has substituted, during his Passover, unleavened cakes for his usual fermented bread—that biscuits are even employed, when fermented bread is not considered sufficiently digestible for the sick—and that the inhabitants of the northern parts of India, and of Affghanistan, very generally make use of unfermented cakes, similar to what are called *scones* in Scotland, Such, then, being sufficient evidence in favour of the wholesomeness of unfermented bread, it becomes important to discover in what respect it differs from fermented bread. Bread-making being a chemical process, it is from chemistry alone that we can expect a solution of this question. In the production of fermented bread, a certain quantity of flour, water, and yeast, are mixed together, and formed into a dough or paste, and are allowed to ferment for a certain time, at the expense of the sugar of the flour. The mass is then exposed in an oven to an elevated temperature, which puts a period to the fermentation, expands the carbonic acid resulting from the decomposed sugar, and air contained in the bread—and expels the alcohol formed and all the water capable of being removed by the heat employed. The result gained by this process may be considered to be merely the expansion of the particles of which the loaf is composed, so as to render the mass more readily divisible by the preparatory organs of digestion. But as this object is gained at a sacrifice of the integrity of the flour, it becomes a matter of interest to ascertain the amount of loss sustained in the process. To determine this point, comparative experiments were made upon a large scale with fermented and unfermented bread. The latter was raised by means of carbonic acid, generated by chemical means in the dough. But to understand the circumstance, some preliminary explanation is necessary. Mr Henry of Manchester, in the end of last century, suggested the idea of mixing dough with carbonate of soda and muriatic acid, so as to disengage carbonic acid, in imitation of the usual effect of fermentation, and with this advantage—that the integrity of the flour was preserved, and that the elements of the common salt, required as a seasoner of the bread, were thus introduced, and the salt formed in the dough. The result of experiments upon the product resulting after fermentation, where soda and muriatic acid were used, has been, that, in a sack of flour, there was a difference, in favour of the unfermented bread, to the amount of 30 lbs. 13 oz.; or, in round numbers, a sack of flour would produce 107 loaves of unfermented bread, and only 100 loaves of fermented bread, of the same weight. Hence, it appears, that in the sack of flour, by the common process of baking, 7 loaves, or 6½ per cent. of the flour, are driven into the air, and lost.* An important question now arises from the consideration of the result of this experiment, viz.—Does the loss arise entirely from the decomposition of sugar, or is any other element of the flour attacked?

It appears, from a mean of analyses of wheat flour from different parts of Europe, by Vauquelin, that the quantity of sugar contained in flour amounts to 5·61 per cent. But it is obvious that, as the quantity lost by baking exceeded this amount by nearly one per cent., the loss cannot

* Proceedings of the Philosophical Society of Glasgow, vol. i. p. 32.

be accounted for by the removal merely of the ready-formed sugar of the flour. We must either ascribe the extra loss to the conversion of a portion of the gum of the flour into sugar, and its decomposition by means of the ferment, or we must attribute it to the action of the yeast upon another element of the flour. And if we admit that yeast is generated during the panary fermentation, then the conclusion would be inevitable, that another element of the flour, besides the sugar or gum, has been affected. For Liebig has well illustrated the fact, that when yeast is added to wort, ferment is formed from the gluten contained in it, at the same time that the sugar is decomposed into alcohol and carbonic acid. Now, in the panary fermentation, which is precisely similar to the fermentation of wort, we might naturally expect that the gluten of the flour would be attacked to reproduce yeast.

A wholesome and palatable bread may be produced by the employment of ammoniacal alum, and carbonate of ammonia, or soda, as a substitute for yeast. In this process the alum is destroyed by the heat—the bread is vesicular and white, and rises, according to the judgment of the baker, as well as fermented bread. It is obvious that none of the ingredients added can affect the integrity of the constituents of the flour—an occurrence which may possibly happen in the preparation of bread by the common process of fermentation, as has been shown, even to the azotized principles of the flour. The disadvantage of such a deterioration is sufficiently evident, if we view these principles as the source of nutrition in flour.

HISTORY.

CHAPTER XV.

THE ROMAN EMPIRE.

Remains of the Capitol.

We dated the commencement of the Roman empire in the year 708 of the city, about forty years B.C., with the appointment of Julius Cæsar to a dictatorship of nominally ten years, but which was intended to be a lease of power renewable till his death. The monarchy founded by Julius embraced the whole territory of the republic, and to this some additions were subsequently made. The unity of this immense empire continued to about the year 450 of the present era, at which period it was divided into the eastern and western empires—Rome being the capital of the latter, and Byzantium of the former. About the year 518, Rome was conquered by the Teutonic invaders; and the eastern empire, although condensed yearly into narrower limits, endured until the overthrow of Constantinople by the Turks, in 1543.

It is altogether a delusion, to fancy that the general liberty of mankind was diminished one jot by the substitution of a real monarchical government in Rome for the forms of a republic. Even at Rome, the forms alone of republican government had survived the usurpation of Marius. To him had succeeded Sylla, to Sylla Pompey, to Pompey Cæsar, with a sway as absolute as that of any of the emperors. The only effect of the institution of imperial sway in Rome, was to limit the number of candidates for sovereignty, and thus diminish the chances of civil war. In the provinces, the change was still less felt; or if felt at all, felt rather as a substitution of comparative tranquillity for incessant wars. Even under the republic, the provinces were not free. The boast of the Roman citizen was, that he was the equal if not the superior of kings. All the citizens regarded themselves as of royal race, compared with the rest of mankind. When they deposed kings, it was not to give liberty to the subjects, but to reign over them in their stead. Under the republic, the denizens of the provinces were either subjected to a partnership government of their old rulers, in company with the Romans, or to the government alone of the Romans, succeeding to all the power of the deposed rulers. Roman liberty was not for the provincials. The change for them at the institution of the empire, was from the dominion of an absolute oligarchy to the dominion of an absolute monarchy. In all absolute governments, the only limit to the sufferings of the people may be measured by the quantity of self-indulgence necessary to saturate the desires of the governor. It is not easy to ascertain the amount with accuracy; but it may safely be predicated, that it is more easy to saturate one man's desires, than to saturate the desires of it may be thousands or millions. The exchange, therefore, from the republican to the monarchical government of Rome, took no liberty from the provinces, for they had none to take, and it was calculated to diminish the amount of exactions from them.

The imperial power was not hereditary. It was granted for a period of five or ten years. This lease, however, was unlimitedly renewable, and in the case of all the emperors, the supreme power was only wrested from them with life. The right of election was at first in the people, but so early as the appointment of Tiberius, the senate assumed the power of appointment, without reference to the people. The *formal* power remained with the senate down to the close of the empire, but the whole military power being concentrated in the sovereign, became more completely organised, and being cotemporary with the decline of civil privileges, the army became the real masters of the state. Augustus organised a permanent camp of prætorian guards in the outskirts of the city, the numbers of which were not only augmented, but another camp was added by his successors. The office of these troops was to enforce the police of the city, &c., and ensure the safety of the emperor. They were the masters of the city; and the noble, wealthy, and ambitious, were eager to be enrolled in so highly privileged a corps. It is evident, that whoever could command the prætorian guards, was most powerful in the state. Now, it must be recollected, that although the Romans had subjected themselves to the sovereign sway of one, the idea of the transmission of imperial power by hereditary succession, never seems to have entered their minds. From the death of Julius Cæsar down to the death of Alexander Severus, a period of more than 250 years, there occur only three instances of the son succeeding his father. The relatives of the reigning monarch had the best opportunities of ingratiating themselves with the troops; and we find, therefore, the sovereignty remaining for limited periods in the same family, but we find no rule of hereditary succession laid down. He who had the most skill to ingratiate himself with the soldiery, was sure to succeed. This point came to an early decision. On the death of Tiberius, the senate met to nominate his successor, but Caius Claudius had secured the army. The senate mustered their guards and household gladiators, but when it was known that the prætorian camp was up in arms, the senatorial guards moved off in a body, and joined the camp. An arrangement was entered into, that Claudius should be elected, but that the senate should go through the form of electing him, without any reference being made to the previous election by the army. This continued to be the rule down to the close of the empire—the senate freely electing the individual chosen by the soldiery, although the business did not always terminate in the same brief and bloodless manner as on the first occasion. The emperor, thus appointed, was absolute. There was no check upon his will,

but the dread of displeasing those who made him. After his death, however, there was a sort of revision—judgment by appeal pronounced on his conduct as monarch. If approved of, he was inscribed in the catalogue of *divi*, the epithet *divus* was ever after applied to his name, and his regulations remained effective until they were superseded by others, or fell into desuetude. If condemned, the meed of commendation was withheld, and all his ordinances regarded as nullified. This, it is clear, could rarely happen, except at the close of a dynasty. It was the case with Nero, the last of the Claudian family.

The subordinate officers of government in the city continued the same under Augustus as under the republic. The election was still in the people. One new officer was added, the *Præfectus urbis*, appointed by the emperor himself, and holding his office during the emperor's pleasure. This officer, with more definite, and yet more extensive jurisdiction than the earlier magistrates, soon eclipsed them. We find, however, consuls, prætors, and quæstors—although sadly shorn of their early power and honours—continuing to be duly appointed down to the close of the empire. In the provinces, the highest local authority was variously bestowed. Augustus reserved under his own immediate control half the provinces, leaving as many to the management of the senate. It was only the less wealthy that the crafty ruler allowed to escape him, nor did they escape him altogether. Each of the imperial provinces was governed by a *Legatus Augusti*, appointed by the emperor, and along with him was sent a quæstor to manage the financial department, to collect the public revenue, to defray the necessary expences of his province (chiefly military) and to remit the surplus to Rome. The provinces allotted to the senate became the perquisites of the ex-consuls, ex-prætors, and ex-quæstors, who succeeded to them according to some secret arrangement among themselves. The management of the revenues of these provinces was not separated from their general government: the governor was not embarrassed by the presence and interference of a quæstor or treasurer independent of him. Even in those provinces, however, there were sources of income—the private property of the head of the state; and to husband and uplift them, the emperor sent a special *procurator*. At first this office was confided to a freedman; subsequently, it was thought not derogatory to an *eques*,—or one of knightly rank. This arrangement continued without material alteration till the time of Constantine, about the year of our era 330. This emperor, shortly after he had transferred his throne to Byzantium, divided the empire into four prefectures. The territorial subdivisions of these prefectures—nearly corresponding with the old provinces—were ruled by officers subordinate to their respective prefects, and called *Rectores* or *Vicarii*. This new arrangement seems to have been suggested by an arrangement which rather earlier had become pretty common—of several co-ordinate or slightly subordinated Cæsars reigning at once. Sometimes this arose from family affection; sometimes from the near equality in power of two or more rivals for the empire. It had its disadvantages, inasmuch as by diminishing the reverence for the imperial power, it weakened the hands of government; but one advantage was strongly felt—the greater manageableness of the public business. The object of Constantine seems to have been to reap the advantage derivable from the division of labour, without weakening the authority of the sovereign. He endeavoured at the same time to introduce a much more essential reform—the separation of the civil from the military power. The prefect, with his subordinated *rectores* or *vicarii*, executed the functions of civil government. The *Duces*, or *Comites rei militarii*, had the management of the *corps d'armée* within their respective provinces. The arrangement of Constantine did not entirely supersede the cotemporary existence of several Cæsars, but it remained the legitimate form of civil polity in later empires, until their subversion.

There remain still some civil authorities to be noticed, not so conspicuous, but equally indispensable in the age of which we are treating, and much more important with reference to subsequent history. We have seen that the whole of Italy and Greece consisted originally of communities collected into cities, and pasturing or tilling the land in their respective vicinities. We have seen that each of these cities was within its own territory, a sovereign self-governing state. We have found traces of the same primeval organization of society in Egypt, in Syria, and within the dominions once possessed by the Carthaginians. We have seen that the manner in which the Greeks extended their territorial power, was by settling cities which possessed all the legislative, judicial, and executive functions, within themselves. We have seen that the Romans consolidated their power by settling colonies wherever they conquered, which, retaining always a certain dependency upon, and sometimes the citizenship of Rome, exercised a wide range of municipal government within themselves. Out of these elements arose the great framework of civil society throughout the entire Roman empire. The great state affairs—the appeal judicial business—the military functions, were discharged by the officers of the central power in Rome. The great bulk of civil and executive business was discharged in every city, with its adjoining territory, by its own home-born magistrates. The organization of these municipalities differed somewhat in Italy and in the provinces. I shall therefore attempt to sketch the constitution of each separately.

First; the Italian municipalities were miniatures of the Roman constitution. They were governed by magistrates, and senators or councils. At first these magistrates and councils were chosen by the people in their assemblies, but in course of time the senates came to arrogate to themselves the power of electing such new members as were necessary to supply vacancies, and to nominate the magistrates. The councils in short monopolized the executive and the constituent powers. The common appellation of these councils was *Ordo Decurionum;* afterwards simply *Ordo;* and in still later times, *Curia*. We find this term *Curia* used in opposition to *Senatus*, the latter designating the great imperial senate of Rome,—the former, the local senate of a municipality. The management of all the internal affairs of the city was confided to the *Curiæ* and the magistrates; the one, however, did not act as a check upon the other, for Decurions alone were eligible to the magistracy, and Decurions elected the magistrates. The retiring magistrate had the right of nominating his successor. The privilege, however, was rather a burdensome one, inasmuch as it rendered him responsible for the actions of that successor. The interference of the governor of the province, when he took upon him to nominate some favourite Decurion, was therefore rarely resisted; and thus the appointment of municipal magistrates fell insensibly to be exercised by the delegates of the central authority of the state. The Decurions were, as long as a distinction was observed in this respect among the denizens of the empire, possessed of the full citizenship of Rome, and were the only members of the municipality who possessed it. It will sound strange, when I add, that with all these apparent powers and privileges over their fellow-citizens, the office of Decurion was shunned under the empire with the agonized energy with which men struggle to escape from a spot stricken with the plague. The plebeians shunned admission into the order, and the Decurion strove to escape the honours appertaining to it. Many joined the army, or became bondmen in the country, in order to conceal themselves; but they were followed to their retreats, and forced back to the Decuria. Jews and heretics were forced under the Christian emperors to become Decurions by way of punishment. Privileges were held out to the base-born, to induce them to become members of Curiæ. The reason was this: the magistrates and Decurions were employed in the levy of the imperial taxes, and were accountable for alleged malversation and negligence to the governor or quæstor of the province. They were also responsible for all their intromissions in city affairs. When estates were deserted by their proprietors on account of exorbitant taxation, the Decurions were bound to make good the deficit with no better relief than the nominal resource against an impoverished community. The chief magistrate, in whom was also vested the judicial power, was elected by the Decurions. At first, there seems to have been no limits to his jurisdiction within his own territory; but, as his office declined in dignity, a concurring judge was frequently appointed by the provincial governor. In some Italian cities there was no Decemvir, the place of that magistrate being supplied by a prefect sent from Rome: his functions were exactly the same. Next in turn came the Curator or Quinquinnalis. The duties of his office were to take charge of the public buildings, to lease out the landed property of the city, and to manage the city revenues. None could be elected Curator, who had not previously passed through all the other offices of the municipality. The magistrates of cities had the right of deputing their power in some cases to private individuals, termed *vices*, or *agentes*. The records and books of court were intrusted to special officers. During the earlier periods of the

empire, *scriba* was the general term for a clerk of court; *excerptor* was a private copier whose services were hired for money. Actuaries and notaries were names for the same occupation; but the latter also designated one who used abbreviations—wrote a kind of short-hand. In the fourth and fifth centuries, excerptor became the general term for a clerk of court; and every *Curia*, or court, had one. In the judicial establishment he had certain fees allotted to him. The title *Notarius*, was now limited in its application to the imperial chancery, and there were among the *notarii* many gradations of rank. The chief—those who made up the lists of public officers and their salaries—were also termed *tribuni*. The persons employed without any public appointment in preparing contracts, testaments, &c., were called towards the termination of the western empire, *tabuliones;* subsequently they received the appellations *amanuenses, cancellarii.*

These are the leading features of the municipal constitutions of Italy. The provincial municipalities retained doubtless for a long time many of the peculiarities of their original constitutions previous to their conquest by the Romans. Under the empire, however, all these varieties were gradually, almost insensibly obliterated, and the whole conformed to one uniform standard. Many of the regulations regarding the Decurions, calculated to entice or press citizens into the office, being only necessary under the empire, were not universal in their application. One essential difference between the Italian and provincial magistrate consisted in this:—In Italy, the office inferred an onerous duty, but conferred in return a certain rank. In the provinces the magistracy conferred no rank: the only provincial sources of rank seem to have been connected with the public ritual of religion. The head of the provincial Decurions was merely a principal; he was merely the chairman or speaker. The ordinary jurisdiction was in all such cities in the hands of the Roman governor, and was partly exercised by him in person during his frequent circuits, or by his legates. From this rule, some few provincial cities were exempted, upon which the same right as the Italian cities had been conferred. To compensate the other cities for their want of self-jurisdiction, there was bestowed upon them about the year of our era, 365, a class of officers called *Defensores.* These were elected by the whole body of the citizens. No Decurion was eligible. The office was to defend the citizens against the encroachments of the provincial governor. The importance attached to this office induced some of the later emperors to attach to it a jurisdiction in cases of small amount; and this innovation was followed up in some *curiæ*, which availed themselves under a lax government to do for themselves what the central authorities neglected to do, by admitting the Defensores into the assembly of the Decurions; and, finally, by making them its chairmen.

These are the respects in which the Italian and provincial *Curiæ* seem to have differed: in the following their constitution seems to have been much the same. The regular number of Decurions appears to have been 100, although the rule was not very strictly observed. The *Album* or roll, contained honorary members, *Patroni*, and ordinary members. The *Patroni* stood first on the roll, and were made in two ways:—First, when Decurions were exempted from active service, because they had filled high offices of state; and, second, when the *Curiæ* promoted to that rank eminent men, not already Decurions, either in compliment to these individuals, or with the view of increasing the respect for their own body. Among the ordinary Decurions stood first, all who had been magistrates, and they were classed according to the rank of their offices. When several had filled the same offices, they were classed according to the length of their service. The ordinary Decurions, who had not filled any magistracy, were classed according to the length of time they had sat in the Curia. In cities where there were no magistrates, length of service, alone, decided the rank of the Decurions; and, by the same rule, the director or president of the Curia—principal as he was termed—was also generally chosen. *Decemprimi*—ten first men—were distinguished from the rest on the roll in cities without magistrates. Sometimes the whole responsibility was limited to them, and sometimes they enjoyed immunities regarding corporal punishment; but their fines were higher than those of the other Decurions. They seem, however, to have possessed no exclusive power.

Having now sketched an outline of the civil institution of the Roman empire, it only remains, in order to give a complete view of its constitution, to point out the character of the laws administered in the courts we have indicated, and the sources whence they emanated.

From the accession of Augustus, *Plébiscita*, or laws enacted in public meetings of the whole citizens, continued to be tolerated for some fifty years. After that time, the power of enacting laws—*senatus consulti*—was reserved in the senate, which continued occasionally to enact them down to the termination of the empire. The edicts of prætors, ædiles, and togati, continued to possess a legislative authority, more or less restricted in its extent. To these come now to be added the *rescripts* of the emperor, or those more comprehensive expressions of his will termed *constitutiones.* Subsequent to the time of Constantine, and the removal of the seat of government to Byzantium, the most influential statesmen used the Greek as their native tongue, and its influence was sensibly felt in the further progress of Roman law, which fell to be expressed in a language not possessed of exact synonyms for its technical terms, and altogether worse adapted for purposes of legal discussion. Previous to this, however, the systematic study of law in schools had increased to a great extent, and the effects of this were sensibly felt in the more humanized and rationalised character of the law. The *exparté* opinions of eminent lawyers became even more deferred to as an authoritative source of law than under the republic. Law became from the circumstances of the empire pre-eminently the favourite pursuit of civilians. Unless a man, determined to rise at court political eminence was out of the question. Eloquence, only of avail amid popular institutions, rendered its possessor an object of peevish suspicion. It was in the department of law alone that active and ingenious minds found a field worthy of them; and the intellectual character of the science was advanced in proportion. This, however, was a mode of advancing legal skill and knowledge which little availed the public at large. The organization of the courts of justice continued as defective as under the republic. The sources of legal knowledge grew more voluminous and unmanageable every day. The Roman law had become, doubtless, a highly elaborated, ingenious and refined system, but its very bulk made it a sealed book to the multitude, and the paucity and defective organization of the courts of justice made even a hap-hazard draw for a prize as in a lottery generally unattainable.

Having now given a rude outline of the constitution of the Roman empire, it remains to test the value of that constitution by its working.

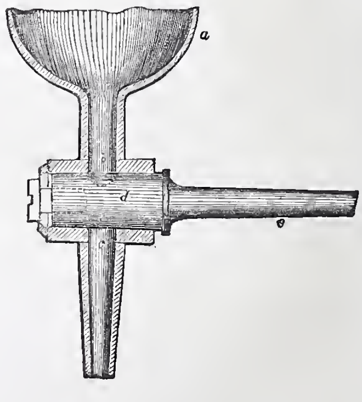
To estimate aright the workings of the imperial constitution, we must recall to mind the plight in which the whole territory included within its sway stood at the overthrow of the republic. Italy had been drained of its population by long wars; vast tracts were deserted, and great part of the rest cultivated by slaves. In a few places there were appearances of wealth and luxury. Rome was the receptacle of the tribute of a conquered world; the busy centre to which the ambitious flocked to further their ends, carrying with them treasures to swell its stores. On every hill-top, for miles around, might be seen the princely villas of the wealthy citizens; and similar gay objects dotted the southern shores of Italy. In Alexandria there was wealth and commercial enterprise. It was the common centre, where met the commerce of the Mediterranean with the commerce of the Upper Nile and Red Sea, and the regions beyond. There was also a flourishing school of literature and science in Alexandria. In Byzantium there was, likewise, much commercial enterprise; it was the spot in which the commerce of the Euxine met the commerce of the Mediterranean. Athens, mid-way between Byzantium, Alexandria, and Rome, was likewise a considerable commercial entrepot; and, like Alexandria, it possessed an eminent school of literature and science. All along the coasts of Syria and Asia Minor, of Cyrene, Sicily, and southern Italy, and of the Euxine, the commercial spirit which received an impetus from the three centres of activity we have mentioned, were active, enterprising, and flourishing; and, from each staple, as from a subordinate centre, radiated lines of competence and bustle into the inner land. At the bottom of the Gulf of Genoa the Massilian colony was the rendezvous to which the rude merchants of Gaul and the far Britain brought their products to receive in exchange the wares of countries further advanced in civilization. And in turn from Massilia, Alexandria, Athens, and Byzantium, did wealth flow to Rome with a steady unintermitting tide—not that there was commerce there to attract it, but because there was

throned the power to which earth was tributary. It will be remembered, that the owners of the wealth distributed in this manner throughout the empire were in part Romans—a not very refined people, familiar with voluptuousness, tyros in art and science, masters in war, irreligious, because their sense of religion had grown dull through familiarity with worldly business, overbearing because they had conquered the earth, cruel and accustomed to feed their cruelty with gladiatorial sports. Among this people the old patricians had died out; the distinctions among themselves were reduced to rich freemen, poor freemen, and slaves; and, while the wealthy were becoming daily more corrupted, the poor were sinking daily nearer to the level of the slave in sentiment. Next in importance to the Romans were the Greeks, less brave, but more humane, a less veracious, but more polished race. They, too, might be regarded as irreligious; but, while the Romans had merely grown callous to the sense of veneration, the Greeks bodied forth one conception of divinity after another, until they became bewildered amid the multiplicity of their own creation, and the feelings of the worshipper died away to leave room for the expanding feelings of the artist. Equally voluptuous with the Roman, the Greek regulated his excesses by good taste. Conscious that the Roman was his master, the Greek sought consolation in the idea that he was his master's teacher. Scattered amid these two master races were in the south the old Egyptians, the Chaldeans, Hebrews, and Phenicians, cherishing the fragments of an older civilization, and clinging to their temples, to compensate themselves for the loss of their national tribunals. In the north and west were the Gauls, and a few Germans, deriving civilization from their masters, as they had in turn learned it from their slaves. This was the surface of society at the close of the republic; a surface incessantly shattered and disturbed by wars and civil convulsions. Even the short-lived intervals of peace were rendered insecure by hordes of pirates and robbers—the remainder of the scum which had boiled over in war.

The first result of the transition to the imperial sway, was longer and more settled intervals of peace, at least in the central provinces. Upon this followed the almost total extirpation of pirates and robbers—the executive power being lodged in one hand, and fewer hinderances being thus placed in the way of its exercise. For a time, the favour of the court shone upon literature, and when the character of the despot began to display itself more unreservedly, the better spirits devoted themselves in haughty self-respect to study, rather than seek degradation by mingling in public affairs. Some of the noblest characters of Rome belong to this period—men who had brooded over the history of their country, until they had tracked out the actions in it with a hundred ideal excellencies, and then, in seeking to rival the creatures of their own imagination, far excelled the realities. There was found a pure pleasure in the education of their children; and among the wealthy, the science of education reached a high grade of development; what they lacked, was the power of diffusing its blessings. Now comes the reverse of the picture: the number of slaves emancipated during the civil wars for the purpose of recruiting armies, had further lowered the character of the poorer and provincial freemen. The oppressive collection of the taxes in the municipalities, as we pointed out above, was breaking the spirit of the people, and depopulating the provinces. The local governors had no check, and the necessity of conciliating the courtiers rendered men more rapacious than their greedy natures would have prompted. There was no longer any distinction between the Roman citizen and other denizens of the empire; but the equalization had been effected by lowering the citizen to the level of the dependents. The central government pressed down the people, and the vices, engendered by habits of oppression and extortion, amply avenged the people by the atrocities they drove the tyrants to perpetrate upon each other. The only schools of virtue—and it was after all but a rude and churlish virtue—were the armies on the frontiers, and imperfectly subdued provinces. Valour and skill in arms kept the intellect from slumbering, and the heart from growing entirely corrupt. But even this supply of good and great citizens was cut off by the jealousy of the court. It became as dangerous to be eminent in military as in civil affairs. Court buffoons and voluptuaries—a prætorian soldiery, dangerous only to the citizen, not to the enemy—a prince swelled by pride, yet degraded by vice—and a timid, deceitful, diminishing population—this is the picture of society in the advanced age of the empire. It became unable to defend itself from the inroads of the warlike tribes on its frontier; it was obliged to receive some of these into pay, in order to ward off the rest—to pay black-mail to these imperfectly civilized freebooters. In the frequently disputed successions to the throne, the arms of these foreign mercenaries came to be used in civil broils. They had already engrafted the skill of Rome upon their own valour; and they soon learned to feel that they were nearly masters, where they were regarded as servants. They set up for themselves in one province of the empire after another. The separation between the western and the eastern empire facilitated their progress; and still, as they advanced, ruder tribes from behind rushed in to fill their vacant seats. The motion of the northern nations upon the Roman empire in the fifth century was not the result of an impulsion from without, but of an attraction from within. Men think the wind a motive power, when, in truth, it is moved and drawn on by a vacuum—so was it with the Teutonic races. There was room for more guests in the milder and more cultivated regions, and these boisterous guests rushed in to fill them. First Britain, then Gaul, then the provinces north of the Alps, then Spain, and lastly Italy, and Rome itself, were obliged to own a Teutonic master. The short period during which Justinian reannexed the imperial city to the empire, does not deserve to be taken into account. This change of dynasty was, doubtless, attended by much violence and oppression, but nothing like what has been represented. Rome began by conquering her neighbours, and ended by being conquered. In her earlier story, we read much of the heroism of the conqueror, and little of the suffering of the vanquished. In her later story we read much about the suffering of the vanquished, and little of the heroism of the conquerors. The Romans saw these transactions from different points of view. Both stories might be materially different, had we the version of the Sybarites in the former case, and of the Germanic tribes in the latter. Facts speak better than coloured declamation. We shall see, as we advance, that too many Roman institutions survived the change of masters throughout the territories of the western empire, to allow us to believe the exaggerated accounts of the havoc and devastation attendant on the Teutonic conquest. But first I must stop to notice the effects, in a secular point of view, of the most glorious, and yet most soul-inspiring incident in the world's history—the Christian mission.

AUTOMATIC LUBRICATORS.

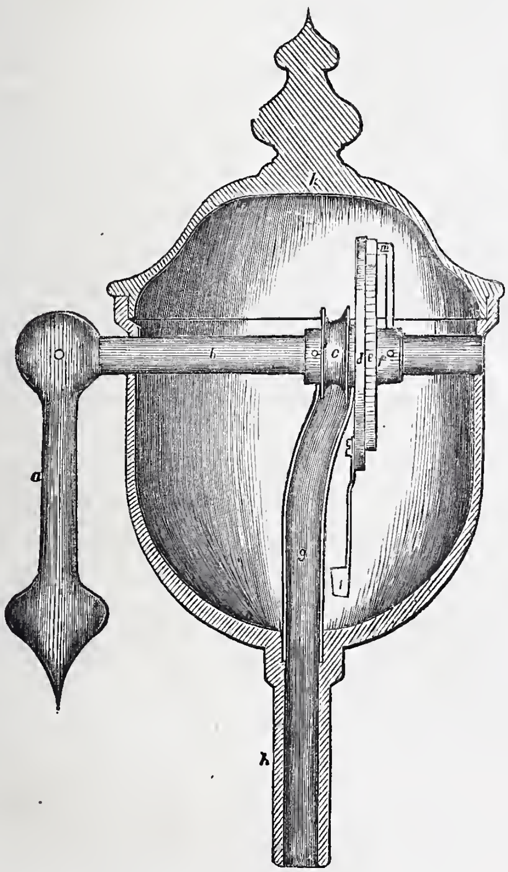
The discovery that the lubricant might be supplied to the journals of machinery by capillary attraction, was a great advance attained over the old irregular mode of supplying it with the oil-can, directly upon the journal. The application of the constant oil-cup, with its skein of cotton, was supposed to admit of little further improvement. A difficulty, however, speedily arose: the oil is supplied to the journal too constantly; for whether this be in motion or at rest, while any oil remains in the cup, it continues to be poured out into the bearing. The supply is independent of the demand; and when the demand is least, the supply is frequently the most profuse. Thus, in a marine engine prepared to start, with its cups all charged, and its siphons in action, some hour or two before the appointed time, the supply meanwhile goes on, and more profusely than afterwards; for when the oil has sunk to a lower level in the cups, during the working of the engine, the oil, having a longer siphon to traverse, makes its way to the journal more slowly. Great waste of oil is in this way incurred; and besides, the very knowledge that the supply is irregular, even although no positive evil should arise from the irregularity, is in itself a feature of imperfection little consonant with the nicety of mechanical adjustment which it is the constant ambition of the mechanist to attain in all his works.



Several remedies for this irregularity have been proposed, of a more or less efficient character. Among the first good conceptions

is that of Mr. Badock, who contrived a mode of rendering the oiling-cup automatic. This consisted in placing a plug-tap, *d*, in the short tube, *b c*, for conveying the oil from the cup to the journal, through the cover. This tap has a cavity at *b*, sunk in one side of that portion of it within the tube, and is prolonged at *e*, to receive a ratchet-wheel, by which the requisite motion may be communicated from some convenient moving part of the machine. The cavity, while on the upper side of the plug, receives its supply of oil from the cup; and by turning it through half a revolution, the same is discharged on the under side upon the journal. In this way, a constant supply of oil is furnished during the working of the engine, so long as any remains in the cup; and it is obvious that the amount will be regulated by the demand: in other words, as the machine goes faster or slower, so will the quantity of oil supplied to it be constantly proportioned to its rate of working; and the moment the engine stops, the process of lubrication will stop also.

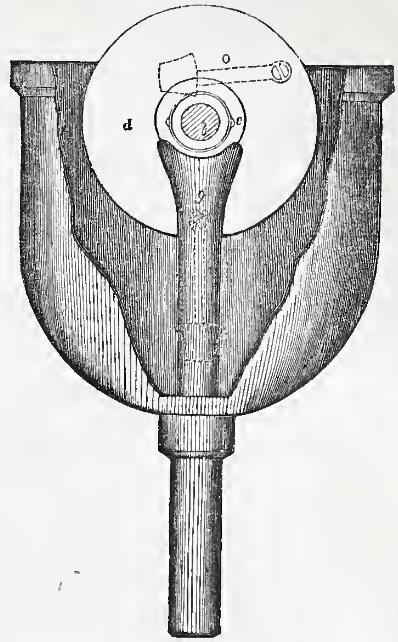
The disadvantage attending the use of this lubricator is, the difficulty of finding a ready and simple mode of connecting the tap with the engine, so as to obtain the required motion. In many cases, indeed, this must prevent its use, even although highly desirable for the particular case; and in general has operated with engineers so as to prevent its being introduced, even under circumstances where such difficulty did not in reality occur.



Mr. Allen's lubricator is in some degree a simplification of that of Mr. Badock; and this again has been further improved by Mr. Muir, who has registered the apparatus as shown in the annexed cuts.

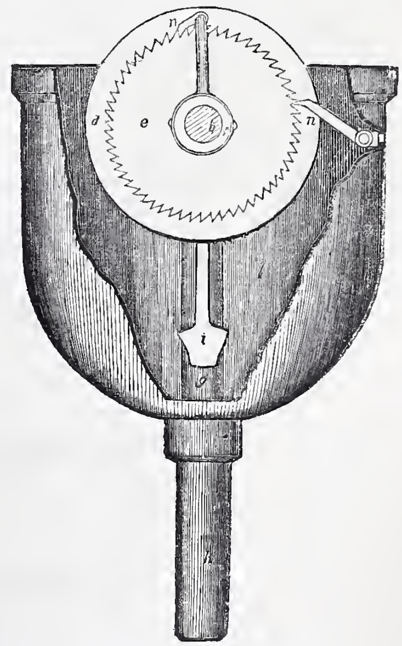
In this, as in Mr. Allen's lubricator, the cup has a spindle, *b*, passing through it, on the end of which is fixed the pendulum, *a*; and within the cup it carries a ratchet-wheel, *e*, which is loose upon the spindle. This wheel carries one or more small buckets, *i*, and is worked by the pall, *m*, attached to an arm projecting from the collar, *f*, fast on the spindle. The wheel is prevented from moving in the contrary direction by the fixed pall, *n*. The ratchet-wheel and plate, *d*, made fast to it, which carry the little buckets, *i*, being made slowly to turn round, the buckets are made to lift the required supply of oil from that in the cup, and to pour it into the tube, *g*, leading to the journal.

To understand the action of the apparatus, let us suppose the engine in motion. The pendulum, *a*, is then caused to oscillate, and carries along with it the spindle, *b*. The pall, *m*, at the same time carries forward the ratchet-wheel, *e*, so many teeth, which, being



Elevation of Cup without Cover, broken to show Bucket-plate, Feed-tube, Roller, &c.

retained by the fixed pall, *n*, ready for the next vibration, in course of time brings the charged bucket, *i*, to the roller, *c*, over which it accordingly empties itself into the tube, *g*. The number of these

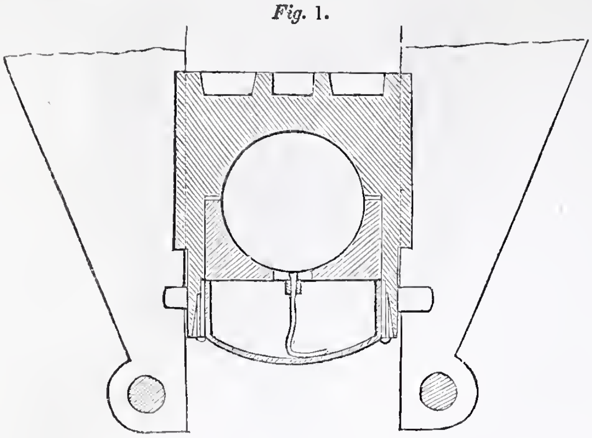


Elevation of Cup without Cover, broken to show face of the Ratchet-wheel.

discharges, in a given time, will, it is easy to perceive, be proportionate to the quickness of motion of the engine, for a given length of arc, through which the pendulum oscillates; and by increasing the length of the arc which the pendulum describes, the motion of

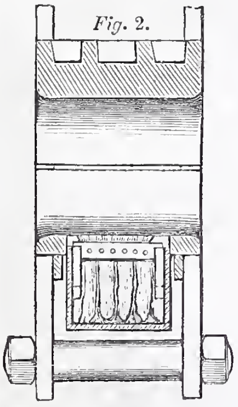
the ratchet-wheel is correspondingly increased, and consequently the supply of oil. Should it be inconvenient to lengthen the oscillation of the pendulum, the same object may be attained by increasing the number of buckets. Various means may be employed to give motion to the pendulum, according to the position in which the apparatus is placed.

Fig. 1.



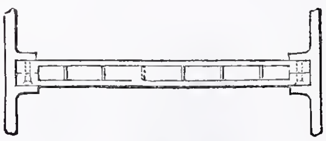
This apparatus differs from that of Mr. Allen chiefly in the use of the lifting-buckets instead of a small piece of wire, which, in Mr. Allen's lubricator, brings up the oil, and drops it upon the discharge roller, over the supply tube. In this arrangement, it is obvious that the supply will vary with the quantity of oil in the cup; for should the oil be low, most of that taken up by the wire will have fallen off previous to its reaching the proper elevation.

Fig. 2.



The apparatus, as modified by Mr. Muir, is nearly as perfect as can be desired for marine and land engines; but the following arrangement seems to us preferable for locomotive engines and carriages, to which the other can hardly be made conveniently applicable.

Fig. 3.



The mode of lubrication to which we refer is in some measure an inversion of the ordinary siphon process, with the advantage that the supply is regulated by the demand, and all waste of oil thereby obviated.

Fig. 4.

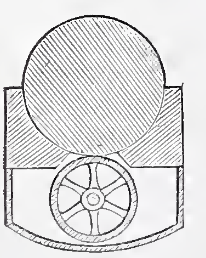
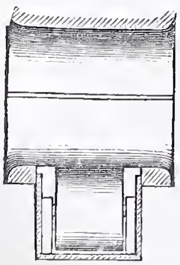


Fig. 5.



One form of the apparatus which may be employed, is represented by the annexed diagrams; of which fig. 1 is a transverse section of the axle-box of a locomotive engine, with the apparatus applied; and fig. 2 is a longitudinal section of the same, fig. 3, a plan of the apparatus itself, showing also the mode of fixing it in the box. Fig. 4 is a transverse section, and fig. 5 a longitudinal section, of the axle-box, with the oil-box lubricating roller in position. Immediately under the journal, a narrow groove is cut in the brass, of about two-thirds of its length, and of a double dove-tailed section, as shown in fig. 1, to receive the lubricating siphon, which consists of a quantity of cotton-wick laid lengthways, and maintained between two thin slips of metal, which form a slight frame, not unlike the flat burner of a common oil-lamp. These slips can be separated when taken out of the oil-box, to allow of the old cotton being removed, and new material supplied. Into one slip a number of small pins are fixed, which are received into a small groove on the inside of the other slip. These are to prevent the cotton from falling down during the running of the locomotive. The siphon may, with advantage, be formed of worsted; or, better, of a quantity of soft hair, held compactly together.

The oil-box is in length about four-fifths the length of the bearing, and, passing on dovetail slides up between the cheeks, is held in its place by two spring catches, which, on being pressed back, allow the box to be taken out.

The siphon-carrier is supported at the proper height in grooves in the ends of the box, and is constantly pressed upwards by springs placed in the grooves under the ends. By this means the lubricating siphon is kept in contact with the journal, and supplies the oil, by its capillary action, continuously as the journal revolves in contact with it.

One particular objection which may be urged to this apparatus is, the soiling of the feeding siphon by the carbon of the decomposed oil, and particles of metal from the wearing surfaces. By this the action of the lubricating surface may be impaired, and possibly stopped, if the trimming process be too long deferred. To remove this objection, the apparatus may be modified, by using a roller to carry up the oil to the journal, as shown in the annexed sketches.

The roller projects through the under brass, which is cut as before to receive its upper surface into contact with the journal. It may be formed of thin brass, or the like, with light arms, to economize the space for oil in the box, and have its surface covered with any textile fabric, such as flannel, to insure its carrying up the requisite supply of oil. The journals are supported on bearings, which slide in grooves, formed as before, on the ends of the oil-box, and are constantly pressed upwards by small serpentine springs placed under them. If the box be made deeper than the proportion shown, two rollers, placed in contact with each other, may be employed; and probably this will, in general, be found the most advantageous arrangement. The principal objection to either form is, the high velocity of the lubricating surface.

Either of these modes of lubrication may, we presume, be applied with considerable advantage in cases where the pressure is mainly upon the upper brass of the bearing, and also when it acts laterally. It might be thought inexpedient to resort to the same means when the weight is downwards, as the supporting bearing would, by the removal of a portion of metal, to a certain extent be weakened.

It ought to be mentioned, that a mode analogous to that previously described, has been proposed by Mr. Babbitt, the patentee of the antifriction axle-box; but the arrangement is too complicated to be very generally brought into use, and is much more liable to derangement than either of the simple forms of the apparatus we have described. Instead of the cotton siphon being laid vertically, as in the mode described, it is supported lengthways against the journal, on a slip of metal, which is made to press upwards by a weighted lever. The two ends of the siphon dip into the oil at the bottom of the box, where they are fastened, to prevent the siphon from being taken in by the journal. The box is of the form of a small *drawer*, which slides laterally into its place.

This apparatus might be rendered more convenient than it at present is, by attaching the slip upon which the siphon is supported to a flat spring, having its ends fixed to two nuts upon a right and left-handed screw, by which they may be travelled, so as to elevate and depress the siphon bearer at pleasure. This would afford a ready mode of increasing and diminishing the pressure of the lubricating surface against the journal, and also of allowing the drawer to be taken out when necessary.

We do not conceive, however, that this form of the apparatus can be so well intrusted as the analogous arrangement above described; and it is greatly more complicated, costly, and liable to derangement.

For the smaller journals of locomotives, we do not conceive that the common siphon mode of lubrication can be much improved. The siphon might indeed be made to furnish the supply upwards, as in the mode described; but the saving which would be effected does not seem sufficiently important to induce alteration.

ON THE EFFLUX OF GASEOUS FLUIDS UNDER PRESSURE.

By Charles Hood, Esq., F.R.S., F.R.A.S., &c.

(Read before the Institution of Civil Engineers.)

The theoretical determination of the velocity with which gaseous fluids are discharged through tubes and apertures under pressure has often been submitted to mathematical investigations, and the subject being of importance in various branches of practical science, it is to be regretted that considerable differences exist in the results of the several formulæ which have been propounded for its elucidation. Dr Papin,* in 1686, first showed that the efflux of all fluids follows a general law; and that the velocities are inversely as the square roots of the specific gravities. Dr Gregory† has likewise given various formulæ for calculating the velocities of air in motion under different circumstances; and Mr Davies Gilbert,‡ Mr Sylvester,§ Mr Tredgold,‖ and many other writers of equal authority have also investigated the subject.

The hydrodynamic law of spouting fluids has by all writers been applied in the calculations for the determination of this question. This law, it is well known, is the same as that of the accelerating velocity of falling bodies, and is proportional to the square root of the height of the superincumbent column of homogeneous fluid. But although the various writers all agree in this fundamental principle, they differ materially in the mode of applying it, and in the several corrections introduced in their theorems: and the results they have arrived at are of a very contradictory character.

Dr Gregory's formula for calculating the velocity with which air of the natural density will rush into a place containing rarer air, is based upon the velocity with which air flows into a vacuum. This is equal to the velocity a heavy body would acquire, by falling freely from a height equal to that which a homogeneous atmosphere would have, whose weight is equal to 30 inches of mercury. The height of this homogeneous atmosphere is 27,818 feet, and the velocity which a body would acquire by falling from this height (and consequently the velocity with which air will flow into a vacuum) is $\sqrt{(27818 \times 64{\cdot}36)} = 1339$ feet per second. The density of the rarefied air, divided by the density of the natural atmosphere, and this number subtracted from unity, represents the force which produces motion; and the square root of this number multiplied by 1339 feet (the velocity with which air rushes into a vacuum) is the velocity with which the atmosphere will rush into any place containing rarer air.¶

The method employed by Mr Davies Gilbert is also based upon the velocity with which air rushes into a vacuum, when pressed by a homogeneous atmosphere, equal to the weight of the natural atmosphere at the earth's surface. This supposed homogeneous atmosphere is, according to Mr Davies Gilbert's calculation, 26,058 feet, and the velocity with which air would rush into a vacuum when pressed by this weight, will be $\sqrt{(26058)} \times 8 = 1295$ feet per second. When this calculation is applied to two columns of air of unequal density; as for instance, the discharge of air through a chimney shaft; the height of the heated column of air divided by the height of this homogeneous atmosphere, and the square root of this number multiplied by the velocity with which air flows into a vacuum, and this product again multiplied by the square root of the number, representing the expansion of the heated air, will give the velocity in feet per second. The expansion of air, when heated, is found according to Mr Gilbert, by raising the decimal 1·002083 (which represents a volume of air expanded by 1° of Fahrenheit), to the power whose index is the number of degrees which the temperature of the air is raised; or it is equal to the fraction $(\frac{481}{480})^n$, the exponent n being the number of degrees of Fahrenheit, which the temperature of the ascending column exceeds that of the external atmosphere.**

Mr Sylvester's method of calculation proceeds upon the supposition, that the respective columns of light and heavy air represent two unequal weights, suspended by a cord, hanging over a pulley; and this mode of calculation gives a result very much less than by any other method.

The unequal weight of two columns of air is found by Mr Sylvester in the same manner as by Mr Gilbert. The volume of air expanded by 1° of heat is equal to 1·00208; and this number, when raised to the power whose index is the excess of temperature of the heated column, gives the expanded volume of the air; and assuming the atmospheric density to be unity, we have $1 - \frac{1}{(1{\cdot}00208)} = d$, in which e is the excess of temperature of the heated column, and d the difference of density between the two columns. This difference of density, multiplied by 8 times the square root of the height of the tube or shaft, containing the heated air, gives the velocity in feet per second.*

In Mr Tredgold's theorem for calculating the efflux of air, the force which produces motion is assumed to be the difference in weight of a column of external, and one of internal air, when the bases and heights are the same. The difference of temperature of the two columns by Fahrenheit's scale, divided by the constant number 450 *plus* the temperature of the heated column, and this quotient multiplied by the height of the tube or shaft, gives the difference in weight. Then, by the common theorem for falling bodies, eight times the square root of this number will give the velocity in feet per second; or accurately $V = \sqrt{\frac{64\frac{1}{3} h (t-x)}{450+t}}$, in which h is the height of the tube, t the temperature of the internal, and x the temperature of the external air.†

The method of calculation proposed by Montgolfier appears, however, by recent experiments to be the most accurate, as it is also the most simple of all the modes of determining this question. The difference in height must be ascertained, which two columns of air would assume when the one is heated to the given temperature, the other being the temperature of the external air; and the rate of efflux is equal to the velocity that a heavy body would acquire by falling freely through the difference of height.

The space which a gravitating body will pass through in one second we know to be 16·09 feet; but by the principle of accelerating forces, the velocity of a falling body, at the end of any given time, is equal to twice the space through which it has passed in that time; or the velocity is equal to the square root of the height of the fall multiplied by the square root of 64·36 feet; or again, to the square root of the number obtained by multiplying 64·36 feet by the height of the fall in feet.

When the *vis viva* is the difference in weight between two columns of air, caused by the expansion of one of these columns by heat, the decimal ·00208, which represents the expansion of air by 1° of Fahrenheit, must be multiplied by the number of degrees the temperature is raised, and this product again by the height of the heated column. Thus, if the height of the column is 50 feet, and the increase of temperature 20°, we shall have $20 \times {\cdot}00208 \times 50 = 2{\cdot}08$ feet: or 52·08 feet of hot air will balance 50 feet of the cold air: and the velocity of efflux of the heated column, when pressed by the greater weight of the colder column, will be equal to $\sqrt{(2.08 \times 64)} = 11{\cdot}55$ feet per second.‡

The efflux of air under any given pressure can also be calculated by the same means. For, the pressure being known, it is only necessary to calculate the height of a column of air which would be equal in weight to this pressure. Thus, if the pressure be equal to one inch of mercury, water is 827 times the weight of air, and mercury 13·5 times the weight of water; therefore $827 \times 13{\cdot}5 = 11164$ inches or 930·3 feet: and according to the preceding formula, $\sqrt{(930{\cdot}3 \times 64)} = 244$ feet per second for the velocity of efflux under this pressure of one inch of mercury.

* Phil. Trans., 1686. † Gregory's Mechanics, Vol. i., p. 513.
‡ Quarterly Journal of Science, Vol. xiii., p. 113.
§ Annals of Philosophy, Vol. xix., p. 408.
‖ Tredgold on Warming Buildings, p. 76.
¶ Gregory's Mechanics, Vol. i., p. 515.
** Quarterly Journal of Science, Vol. xiii., p. 113.

* Annals of Philosophy, Vol. xix., p. 408.
† Tredgold on Warming Buildings, p. 76.
‡ This, which is the usual mode of calculating the expansion of air, differs considerably from that already given, employed by Mr. Davies Gilbert and Mr. Sylvester; and also from the formula of Dr. Gregory. The calculation of the latter is based on the fact, that air expands ·376 for 180° of Fahrenheit, the original volume at 32° being 1; and, therefore, he uses the expression $(1{\cdot}376)^{\frac{x}{180}} = V$, in which x is the required temperature, and v the volume at that temperature.—(*Gregory's Mechanics*, vol. i., p. 486.)

In all these cases the velocity thus ascertained is independent of any loss by friction. A certain deduction must be made for this loss which will vary greatly according to the nature and size of the tube or shaft through which the air passes, as well as with the velocity of the air. Like all other fluids, the retardation of the air by friction, in passing through straight tubes of any kind, will be *directly* as the length of the tube, and the square of the velocity; and *inversely* as the diameter. This question, however, becomes very complicated under these circumstances, and particularly so when there are angular turns in the tube through which the air passes. The present state of our knowledge on this subject does not allow of any very accurate determination of the amount which ought to be deducted for friction from the initial velocity obtained by calculation; and it is only by empirical means we can arrive at an estimate of its amount.

We shall proceed now to ascertain how far these theoretical calculations agree with the results obtained by experiments.

In some new furnaces which Sir John Guest has lately added to his extensive iron works at Dowlais, some experiments have been made on the quantity of blast injected into the furnaces. In these experiments the machinery employed being new and of the best construction, the loss occasioned by the escape of air through imperfections of the apparatus was perhaps as small as possible. The engine for blowing the furnaces made at the time of the experiments eighteen double strokes per minute. The diameter of the blowing cylinder was 100 inches, and the effective length of the stroke 7 feet 6 inches. From these dimensions, therefore, it appears that 14,726 cubic feet of air was taken into the blowing cylinder per minute; and the tubes through which it was discharged from the receiver were six of 4 inches diameter and six of $1\frac{1}{4}$ inch diameter: the area of all these tubes was therefore ·5747 of a square foot, and the pressure of the blast, measured by a mercurial gauge, was equal to $4\frac{1}{2}$ inches of mercury. Calculating by the formula already given we shall have $\sqrt{(827 \times 13{\cdot}58 \times 4{\cdot}5 \div 12 \times 64)} = 519{\cdot}2$ feet; which is the velocity per second; and this number multiplied by 60, and then by the area of the tubes, will give $519{\cdot}2 \times 60 \times {\cdot}5747 = 17{,}903$ cubic feet of air discharged per minute. From this amount some deduction must be made for friction. The velocity of the discharged air is 354 miles per hour; and with this immense velocity and through such small pipes the friction is no doubt considerable. By deducting 18 per cent. from the calculated amount of 17,903 cubic feet, we shall have 14,681 cubic feet, which agrees within a fraction (namely 45 feet) with the quantity obtained by measurement.

In other experiments made at the same place, the following were the results:—The quantity of air which entered the blowing cylinders was the same as before; namely, 14,726 cubic feet; the total area of the tubes which discharged the blast was ·5502 of a square foot, and the pressure of the blast was equal to 4 inches of mercury. The calculation, therefore, will be $(827 \times 13{\cdot}58 \times 4 \div 12 \times 64) = 489{\cdot}5$ feet per second; and, therefore, $489{\cdot}5 \times 60 \times {\cdot}5502 = 16{,}159$ cubic feet discharged per minute. The velocity of the blast in this case was 333 miles per hour; and if we deduct for friction 9 per cent. from the calculated amount, the remainder is exactly the quantity of air which is ascertained by experiment to be discharged through the tubes.

In a work published in 1834, by M. Dufrenoy, being a Report to the Director-General of Mines in France, on the use of the hot blast in the manufacture of iron in England, the results are given of many similar experiments to the above; but, with two exceptions, the details are not sufficiently ample to found any calculations upon. The two exceptions named are the furnaces at the Clyde and the Butterly Iron Works, when they were blown with cold air. Both these blowing machines are described as having been in use for several years, and it is, therefore, natural to suppose the various parts were more worn, and fitted less accurately, than in those experiments already described. The experiments were also made with less care. They show a different result to those already detailed; as in these the calculated quantity of air appears to be less than the quantity which entered the blowing cylinders, in about the same proportion as it exceeded it in the former cases. This difference, no doubt, arises from the imperfect fitting of the piston of the blowing cylinder, which, by allowing a portion of air to escape, would diminish the apparent pressure on the mercurial gauge, placed at the further extremity of the apparatus, and thence the calculated rate of efflux would, of course, be diminished.

In the experiments at the Clyde works the quantity of air which was discharged into the furnace, when estimated by the quantity that entered the blowing cylinder, was 2827 cubic feet per minute. The pressure of the blast was equal to six inches of mercury, and the area of the tubes ·0681 of a cubic foot. Calculating the discharge of air under this pressure, it amounts to 2450 cubic feet, being 13 per cent. less than the measured amount, supposing no loss to occur by imperfect fitting of the apparatus.

At the Butterly works the quantity of air discharged into the furnace, estimated by the contents of the cylinder, was 2500 cubic feet per minute. The pressure of the blast was equal to 5 inches of mercury, and the area of the tubes ·0681 of a cubic foot. The quantity, by calculation, appears to be 2235 cubic feet, being less by $10\frac{1}{2}$ per cent. than that shown by experiment. In both these last cases, however, there is but little doubt that the loss of air from the cylinder caused the pressure on the mercurial gauge to be less than it would have been, had the apparatus been perfectly tight; and a very small diminution in the observed height of the mercury would account for a much greater difference in the velocity of efflux than is here shown.

We are fully warranted in the conclusion, from these experiments, that this method of calculation is as accurate as any theoretical determination of such a question can be; but from the results so obtained an allowance must always be made for friction, which will, necessarily, vary with the peculiar circumstances of each case.

The following table will exhibit the results of the preceding experiments at one view:

TABLE No. 1.

Place and No. of Experiment.	Pressure of Blast in inches of Mercury.	Area of Tubes. (Square feet).	Velocity of Blast. (Miles per hour).	Quantity of Air, by Experiment. (Cubic feet).	Quantity of Air, by Calculation. (Cubic feet).	Difference in Quantity. Per cent.
Dowlais, . No. 1	4·5	·5747	354	14726	17903	+18
Do. . No. 2	4·0	·5502	333	14726	16159	+ 9
Clyde, . No. 3	6·0	·0681	408	2827	2450	—13
Butterly, . No. 4	5·0	·0681	372	2500	2235	—10·5

In order to show the results of the several modes of calculation which different mathematicians have adopted, the following Table has been calculated from the data given in experiment No. 2 of the preceding Table; and it shows how far the several modes differ from each other in their results:—

TABLE No. 2.

Place of Experiment.	Pressure of Blast in inches of Mercury.	Area of Tubes. (Square feet).	Quantity of Air, by Experiment.	Quantity of Air discharged, by calculation.				
				Montgolfier.	Gregory.	Gilbert.	Sylvester.	Tredgold.
Dowlais, ...	4·	·5502	14726	16159	15152	14855	5017	15555

Considering the amount of friction which must result from the discharge of air at the immense velocity which was obtained in this experiment, namely, 333 miles per hour, and also that some of the tubes were only $1\frac{1}{4}$ inch diameter, it will, probably, be

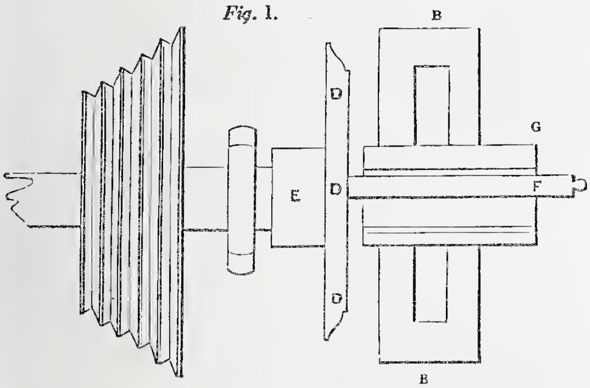
considered, that the highest of these calculations is the nearest the truth, as it only allows of a deduction of 9 per cent. being made for friction, to reduee the calculated amount to the quantity obtained by experiment. It may, therefore, be concluded, that the method which gives this result is the most accurate, as it is also the most simple for general use.

APPARATUS FOR ORNAMENTAL TURNING.

Manufactured by Messrs. CHARLES HOLTZAPFFEL & Co.

Right-Angled Sliding Rest.—The right-angled sliding rest is mounted on a cast-iron bottom piece, A, having a dovetailed groove in the under side, in which the head of the bolt fixing it to the bearers is placed. The upper part of this bottom piece is perforated with a cylindrical hole, into which the lower part of the piece, B, is fitted, and the binding screw, C, fixes it in any desired position. The upper part of the piece, B, is made dovetailed, or with both edges beveled, so that the carriage is easily and seeurely retained on them. It is moved lengthways by the main screw with its milled head; it moves through the space of an inch in ten revolutions, and as its milled head is divided into ten parts, one of its divisions is equivalent to the $\frac{1}{100}$th part of an inch—a division which will be found very convenient for general mathematical or mechanical purposes. The upper part of the carriage is fitted with steel bars, between which works the slide, provided with four screws to regulate its motion. A long screw, having a milled and square head, is called the guide-serew, because the intention is to unscrew it gradually either with the fingers or a winch, whilst its end bears against the carriage, by which means a gradual and steady motion is given to the slide, enabling it to do the work assigned to it equably and with faeility.

Fig. 1.



The arrangement of screws, &c., in the slide, is such, that the oval pieces swing round on one of the outer screws, when the central screws with the square heads are loosened to their fullest extent, thus admitting either the bar which holds the sliding-rest tools, or the various drilling and eutting apparatus. Formerly, these various instruments required a distinct slide for each—a rather expensive and inconvenient mode, from the necessity which then existed for taking the cutting instruments to pieces, to put them in or out of the slide, which their bulk rendered necessary.

The slide is pressed forward by a lever, which has a pin to be inserted in either of the holes in the steel slide-bar, and a hole to embrace the pin fixed in the upper part of the steel clamping-bar for the tools; this will be found to give the hand an easy and sufficient purchase in pressing forward the tool.

As, in many cases, it is requisite to make several incisions or cuts equally deep, it is evident a stationary screw is requisite for preserving the depth of the same; the head of this screw is divided, and there is a small nonius for reading off the divisions in cases where it is requisite the cuts should be successively deeper than one another, which not unfrequently happens. There are two small side-screws, with square heads, to fix whichever of these screws may be required, so as to prevent their being accidentally moved by the hand or other means.

The last improvement in the sliding rest, is the introduction of the cone and screw at the bottom, by which the height of the tool may be adjusted to the centre of the lathe, without removing anything from its place—a point of considerable convenience.

Method of Fixing the Sliding Rest.—Fig. 1 represents the method of fixing the sliding rest for turning a surface. The instrument used is called a set square; it is formed like the letter T, as shown in fig. 1, as marked by D D D F; and, in applying it, the steel blade must bear truly against the face of the work, E, (provided it be flat,) and the metal side against one side of the carriage of the sliding rest, either inside or outside, as may be most convenient. If the surfaee of the work used to set it by is untrue or rounding, it will be found best to turn it slightly hollow, as then the square will have a perfect bearing at the extremes of the diameter, which will be all that is required.

Fig. 2.

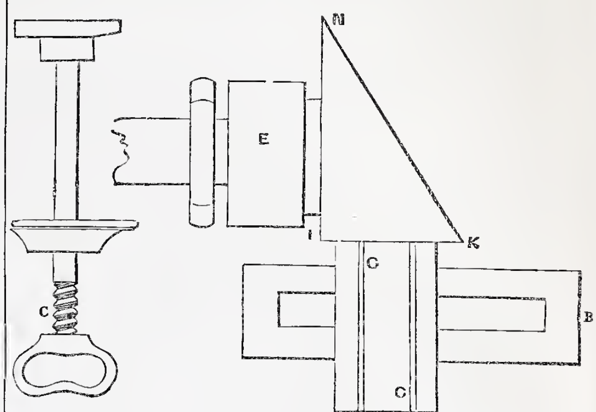


Fig. 2 represents the application of a triangular square, I K N, for setting the rest to turn a cylinder; it will be observed, that the one side of the square bears against the work, E, as in the former manner, and the edge against the front surface of the carriage of the sliding rest.

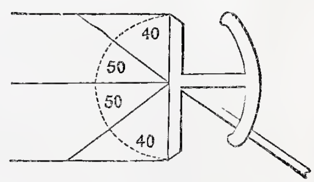
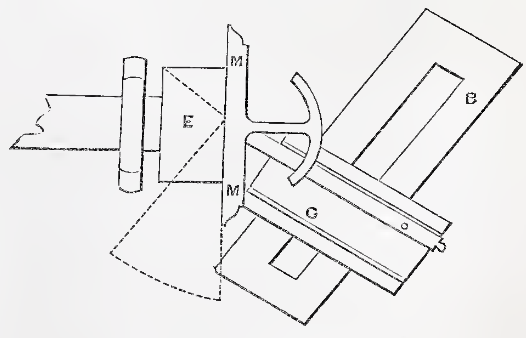


Fig. 3 is an example for turning a cone, or oblique surface. The setting instrument assimilates to the set square in fig. 1, but the steel blade is moveable on an axis at its centre, and has its circular edge divided, to notify the degree of inclination at which it is set; it is requisite to set the sliding rest either from a flat surface, as in the preceding examples, or a cylinder; or if it be from a cone, allowance must be made for the obliquity it already possesses. Suppose, for example, a cone to be wanted, the sides of which form an angle of 100°; by reference to the above

Fig. 3.



Cast-iron bottom piece.

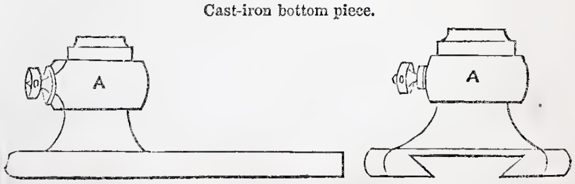


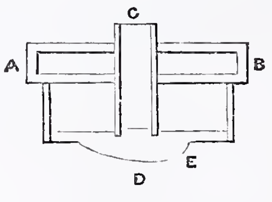
diagram it will observed necessary, that the instrument should be set to 40°, for the sides form with the axis of the cone two angles of 50° each; therefore the instrument must be set at that inclination, which will make with the 50° a right angle, or 90°, namely, 40°, such being the angle the face of the block presents to the sides of the imaginary cone. Things being thus, the metal stem of the instrument will be observed to be at right angles to the sides of the intended cone, in which case the main body of the sliding rest will be parallel to the same, as fig. 3 represents, and will therefore reduce the work to the desired figure. In fixing the slide rest, it is better to begin by fixing the cast-iron bottom piece in the first instance, and afterwards the upper part. To regulate the height of the instrument, there is a screw in the bottom of the circular stem which bears on a portion of the bottom piece.

Apparatus attached to the Sliding Rest, for Turning and Ornamenting Curved Surfaces.—In this application of the sliding rest, the slide, instead of being kept constantly in contact with the main body of the rest, bears upon the edge of a piece of steel, shaped to the curve it is designed to operate upon. The slide, which receives both the common sliding rest tools and the cutting instruments, is provided with a steel roller at the end, (used in a similar manner to the common stop-screw, by being kept coustantly in contact with the curved guide,) which traverses in a groove, and has a screw for adjusting the same, for setting the tool at different depths in the usual way.

The curved guides, before spoken of, are supported at the back of the rest, either parallel with it, or obliquely, as desired, by means of two cross pieces of steel, secured under the ends of the T-shaped piece of the rest by two screws, and two other screws serve to fix the guide to these pieces.

It follows as a matter of course, that if the main screw of the rest is turned, and the slide pressed up by the lever on to its bearing, instead of turning a straight surface or cylinder in the common way, the tool will describe the same curve as the guide-piece against which the slide carrying the tool or cutting instrument is pressed.

It is much the better plan to turn the surface, and subsequently to ornament it without shifting the position of the rest, which can be accomplished by letting the tool project somewhat beyond its usual distance; and before commencing, it is well to try if the two apparatus can be successively employed from the same position of the rest. The construction of the rest will not admit of curves very sudden in their rise, if we may be allowed the expression, and the more particularly when it is wanted to begin at the bottom and rise upwards; as for instance, A B represents the line along which the tool carriage is made to move, and C D the direction in which it is obliged to recede from the work to accommodate itself to the figure to be turned, consequently, when it meets with a curve like the portion at E, in attempting to move the slide

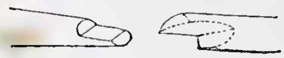


up the same, it would have to move as much in the line C D, or away from the work, that it would not be able to accomplish it, and the whole would wedge fast together; but there would be no difficulty in making it move down the slope, instead of up, and the tool should be withdrawn when it gets to the bottom of the curve, whilst the rest is being moved back again to the top of the same. In those cases where the sudden rise of the curve might not altogether prevent motion, it might offer so much resistance as to strain the whole machine; but we have pointed out how little necessity there is for risking this.

Of course, the successful application of this, as of most other apparatus, will depend much on the taste of the operator; but the guides present, either in their whole length or in smaller portions of them, much variety, and they may be used in different angles with regard to the axis of the lathe, therefore an immense variety of ornamental figures may be made with them. The round-ended drills will be found very generally useful with this apparatus, and many other of those drills which project most at the central part.

The Rose Engine makes very beautiful work with them, and the Universal Cutter may likewise be applied with very great success.

Drilling Instrument.—The drilling instrument, as now mounted, is a steel arbor or spindle, carrying at the one end the boring bits, at the other the steel pulley by which motion is communicated to it from the drilling frame. The spindle works in a steel stem filling the receptacle slide of the sliding rest. The hole in front for the reception of the boring bits is very nearly cylindrical, and the extreme of both the hole and the drill are filed away from one side to the diametral line, so that each presents a semicircle; such being the case, if the end of the drill constituting the semicircle is placed opposite the semicircular *space* made at the end of the socket, it will, by being pushed forward, occupy the vacant space, as may be perhaps elucidated



by the sketch. The two half circles will make together one whole one, and mutually prevent each other turning round as effectually as if they were both square as a tenon and mortice.

This instrument is not only for drilling holes, to which purpose it is perfectly applicable, (with the assistance of the division-plate for determining their distance,) but having bits or drills of various ornamental figures, the ingenuity of the operator will soon discover their uses and produce most pleasing figures. Let it be generally understood, that the drills, like the die for a coin, produce exactly the reverse of their own figure; for instance, if the tool be semicircular, as sketched, it will produce a small bead by being moved in a circle, or portion of a sphere on the work, when the axis is fixed; and so of all the others. All those tools which are highest in the centre, can be used for making a groove or flute; for example, the tool of the shape annexed would, if made to revolve in any fixed position, make a simple dot or portion of a hollow sphere; but if whilst it is revolving, it be slowly moved to the right or left by the screw of the sliding rest, it will make a groove like those in architectural columns. Drills of different figures produce flutes or grooves of different shapes, always the reverse of their own.

Eccentric Cutting Frame.—This is in some degree an extension of the principle of the drilling instrument; it consists similarly of a revolving spindle fitted in a steel stem adapted to the sliding rest, furnished at the one end with a pulley; but the tool, instead of being limited to work in the centre only, may be made to travel in a circle from the smallest limit to about 2 inches; thus of course cutting a circle of that diameter of the reverse figures of the different cutters it possesses. Some specimens of turning now before us, illustrate its application. One is an eight-sided piece of ivory with a hemispherical end; and another a flat piece of cocoa wood, which shows how the frame is used on such surfaces. In the first instance, the block was made eight-sided, (after having been turned cylindrical,) with a round-ended cutter set to make a circle, somewhat larger in diameter than the width of one of the sides of the octagon; this is exhibited by the one side not ornamented. In this example the tool (angular or pointed) has been set in each of the patterns at a distance of $\frac{1}{4}$th of an inch from the centre, thus discribing a circle of half an inch diameter. In the one pattern, the long sliding rest screw has been moved half a revolution between each, thus making 20 in the inch; in another, one whole revolution making 10 cuts in the inch; and in a third, apparently 5 cuts have been made at 2 divisions each, or 50 in the inch, and then one entire revolution of the screw has been made.

Thus, by using various diameters in the circles and different divisions; a great number of patterns may be produced. Another pattern has been formed, by causing the tool to travel in a circle of such diameter as should reach from the centre of the dome to its base, and to make a *semicircular* cut, the tool has been depressed a little below the centre of the mandril, so that it cut into the work at the upper half, but pass below it at the lower.

The effect might have been reversed, by raising the tool above the centre, in which case it would have cut the lower half, and passed the upper without cutting.

The piece of cocoa wood shows other applications of the same instrument. It seems merely requisite to say in the general way, that the arrangement of the pattern having been determined on, the tool is first set (being itself at the central point of the instrument) at the centre of the proposed circle; the

diameter of the tool is next increased, until it makes the circle of the required size; it is then adjusted to the depth of the cut, and the number of circles of which the pattern is to consist; the latter by the division plate. All the patterns in straight lines are made by altering continually the position of the screw of the sliding rest, although in such patterns as consist of several lines all directed to the centre, in the manner of radii, it is admirable to repeat the same dot in each of the radii, after each adjustment,—there being much less chance of error in setting the division plate repeatedly to the same point, than the sliding rest screw, the pieces of the former being in no way shifted, whereas the latter are relationally one to the other.

Universal Cutting Frame.—This instrument is analogous to the circular saw, although usually only a single tooth or cutting instrument is used; but this from the rapidity of the motion, effects almost the same purpose. The cutter is fixed in the centre of the spindle by a side screw; this spindle revolves between centres in a steel arm, and has a small brass bevil pinion fixed near its end, which works in the bevil teeth of a brass spur or drum, on the periphery of which the catgut, giving motion to the instrument, acts. It is also to be noticed, that the spindle can be placed in any position, either horizontally, perpendicularly, or at any obliquity; as the arm which carries the spindle has a cylindrical stem or tail piece passing through and through the slide in which it is mounted, and which can be fixed in any position by the end screw. There is a graduated semicircle and nonius for reading off the obliquity of the spindle in degrees.

This instrument, from the various positions in which it can be placed, in combination with its differently shaped cutting instruments, admits of extensive application and variety. When the spindle is placed vertically, it is used for cutting the teeth of wheels and pinions of every description, and, provided the cutter is properly shaped, it rounds the top of them to the exact figure at the same time.

It admits of application to every description of curved surface, which is not the case with other ornamental apparatus; as, for instance, in urns and some other curvilineal work. In many cases, as in the feet of some urns, by placing the spindle vertically, the whole surface of the work is ornamented in the most finished manner. The curve which the instrument cuts, is one that applies well to a great variety of work, and being exactly circular, it is sure to be pleasing to the eye. It is equally well adapted to other curves, such as form the body part of urns and the like, although it is very difficult to apply other instruments to such figures, without spoiling their symmetry. The flat tool is usually employed for this purpose; and as we must be guided by the surface of the work, the following is the mode of proceeding. The spindle is placed horizontally with the tool at one extremity of the curve, the tool is allowed to make a small cut, being governed in its depth by the stop screw at the end of the slide, and another cut is made in the same circle at the next division which is intended to be used; it must now be observed whether any portion of the original surface remains between the ends of the two cuts just made; if so, the tool must be set in a little deeper, each cut deepened, and the work again inspected. A little patience in the operation of setting the tool, is well bestowed. The point to be attained is, that the tool may be finally set, so as just to remove the surface; it must not sink below it, as if it do, it will be sure to injure the effect of the finished work. The depth once ascertained, the incisions all round that circle can be made without farther trouble. When the first circle is completed, the tool must be moved just as much as its own breadth to the right or left as the case may be, so as to be exactly in contact with its former position, and beginning with a fresh situation on the division plate, the same operation is to be continually repeated.

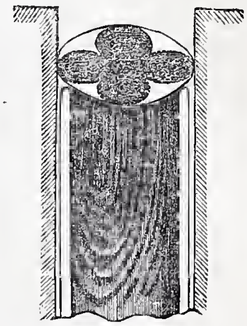
It will be found of great convenience to blacken the surface of the work to be ornamented with a lead pencil or Indian ink, as then the contrast between the ivory and the black, would be so conspicuous, as to save a great deal of trouble in inspecting the work.—We speak of ivory, it being almost the only material used in ornamental work.

SMITH'S IMPROVED SHIP-BLOCKS AND SHEAVES.

The continual destruction of hempen rope and tackle falls, in the naval and mercantile marine, together with the numerous accidents continually occurring in consequence of the splitting of wooden blocks from choking and other causes, induced Mr. A. Smith, the original patentee of the wire rope, and other inventions, to direct their attention to the subject, with a view, by a thorough investigation, to remedy the evils.

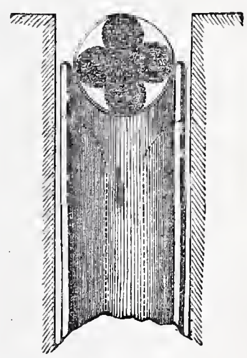
The improvements which resulted from the inquiry are in substance explained by the subjoined figures, which show the form of the old and new sheave.

Fig. 1.



In fig. 1, it will be observed that the sheave, which is of wood, has a groove of a radius much greater than that of the rope designed to work upon it. This is the common form, and, accordingly, when the rope, by tension, and especially when wet, tending to accommodate itself to the flat surface which supports it, becomes compressed, and assumes in its cross section the elliptical form shown in the figure; then, should the strain be considerable, the rope, by yielding beyond the proper allowance for clearance, necessarily chokes the block, and, besides suffering deterioration by distortion and abrasion of its material, not unfrequently separates the cheeks of the block.

Fig. 2.



These evils are remedied by diminishing the radius, and increasing the arc of the groove, (as in fig. 2,) so that its transverse section becomes a semicircle, answering exactly to the rope which it is to receive. By this form of sheave, the rope is preserved under strain in its natural round form, instead of being compelled to take the flat form of the groove in the common wooden sheave.

The new sheaves are of iron, and Mr. Smith states that they are not heavier than the ordinary wooden ones of the same strength, that they will last longer, and are cheaper in the first cost.

The blocks are likewise of iron, and are formed without joining in one piece, and are therefore not liable to split like the wooden blocks. The hook or eye is fastened, or made to swivel, in the shoulder of the block, and, in consequence, requires neither straps nor binding, which are so highly objectionable, yet absolutely necessary, in the wooden blocks. The straps are objectionable, as they suffer greatly by exposure to the atmosphere, and by absorbing and retaining moisture, particularly in the splice at the lower part of the block. This part is, indeed, often entirely destroyed before the other parts are perceptibly affected; and, in consequence, it often happens when tackle, after lying past some time unused, is again applied to raising heavy weights, the strap suddenly breaks, generally at the splice—sometimes in the throat of seizing.

The shell of the metal block is hollow, and strengthened by horizontal and vertical ribs, placed inside to give strength, and leave the exterior without any sharp projections which might do injury to the spars and gear. By this form of construction, the greatest amount of strength is obtained with the least weight of metal; and we are assured, that for the same *size* these blocks are not heavier than iron-bound wooden blocks, while they possess about four times the strength, and will, undoubtedly, last four times as long.

ILLUSTRATIONS OF MECHANICAL DRAWING.

CHAPTER V.

In the few additional papers which we purpose to present on the subject of mechanical drawing, we shall assume that the reader is now familiar with the more elementary geometrical constructions of regular forms, and shall therefore proceed at once to the practical details of the subject.

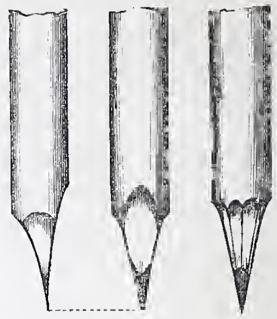
It is perhaps unnecessary to enter upon any particular description of instruments for mechanical drawing. Suffice it to say, that the most essential appurtenances to the drawing-board and T square, are a pair of plain dividers, or compasses, for marking distances; a pair of compasses with a moveable leg, which may be replaced by an ink-pen or pencil leg, as wanted, for the purpose of describing circles of a larger radius; ink and pencil-bows for the description of smaller circles, and a distinct drawing-pen for straight lines. As for pencils, the H B (hard and black) quality is usually recommended; but it is too soft to retain long the fine point usually required for the correct execution of mechanical drawings; and besides, the softer pencils are the more unctuous, and therefore the less ready in taking on ink lines than the harder. F-pencils work pretty well upon smooth paper; but for drawing-paper, of a thick and rougher quality, especially after having been damped and stretched, H H, and even H H H pencils, (of two or three degrees of hardness,) are better suited to retain their sharpness. They are further recommended by the lightness and delicacy of the lines that may be thrown off by them; for where a pencil-drawing is made, with the view of being done over with ink-lines, the excellence of these lines, as well as the readiness with which they are produced, depends much upon the quality of the pencilling.

In constructing preparatory pencil-drawings, then, it is advisable, as a rule of general application, to make no more lines upon the paper than are necessary to the completion of the drawing in ink, and also to make these lines just so dark as is consistent with the distinctness of the work. In regard to the first idea, it is of frequent application; in the case, for example, of the teeth of spur-wheels, when, in many instances, all that is necessary to the drawing of their end-view in ink are three circles, one of them for the pitch-line, and the other two for the tops and bottoms of the teeth; and again, to draw the face-view of the teeth, that is, the edge-view of the wheel, we have only to mark off by dividers the positions of the lines which compose the teeth, and draw four pencil lines for the two sides, and the top and bottom. Many other abbreviations will suggest themselves to the practised draughtsman in the course of his work. And here we cannot help remarking the inconvenience of that arbitrary rule, by which it is sometimes insisted that the pupil shall lay down every line in pencil that is to be done, before drawing it in ink. It is often beneficial to ink in one part of a drawing, before touching the other parts at all: it prevents confusion, makes the first part of easy reference, and allows of its being better done, as the surface of the paper inevitably contracts dust, and becomes otherwise soiled in the course of time, and therefore the sooner it is done with the better.

We remarked also, that the pencil lines ought to be just so dark as to render them distinct, for the more lightly they are executed, the fitter are they to receive the ink. A little practice, and a steady hand, will secure the end proposed. The pencil needs not be held tightly; a slight hold, without slackness, is all that is wanted, inclined a little to the side towards which the line is drawn. Besides a drawing-pencil for straight lines, it is well to have one for sketching in small circles, not requiring the regular application of the bows, as the rounding and filling up of corners, ends of bolts, &c. The straight-line pencil, to be properly cut for use, should in the first place be cut down to the flat side of the lead, in a plane nearly parallel to its axis; then cut away, on the opposite side, to a bevel considerably inclined; and cut likewise, transversely, at equal angles. The lead being thus laid bare, should be cut down gradually on the three inclined sides, till brought to a fine edge, viewed laterally, and a flat round point in the other aspect, as illustrated by figs. 1 and 2. The less inclined side, fig. 1, when applied to the square, admits of the point being brought close to the edge, by which the line is more certainly drawn, and the roundness of the point in fig. 2 evidently enables the pencil to stand longer, before requiring mending. Fig. 3 shows the sharpening of a sketching pencil, which is simply conical, and brought to a fine point. To produce a good working pencil, a sharp knife is indispensable; if the knife be blunt, the point will invariably break away before it is properly brought up.

India-rubber, or caoutchouc, is the ordinary medium for cleaning a drawing, and for correcting errors in the pencil. That substance, however, tends to destroy the surface of the paper; and by repeated application, it so ruffles the surface as to spoil it for good drawing, especially if ink-shading or colouring is to be afterwards applied. It is much better to leave trivial errors alone, if corrections of the pencil may be made alongside without material confusion;—time enough to clear away all superfluous lines when the inking is finished.

Fig. 1. *Fig.* 2. *Fig.* 3.



To draw lines in ink with the least amount of trouble to himself, the mechanical draughtsman ought to take the greater amount of trouble with his tools. If they be well made, and of good stuff originally, he ought carefully to preserve their working parts from injury, keep them well set, and, above all, to keep them scrupulously clean. The setting of his instruments is a matter of some nicety, for which purpose a small oil-stone is convenient. To dress up the tips of the blades of the pen, or of the bows, as they are usually worn unequally by continued usage, they may screwed up into contact, in the first place, and passed along the stone, turning upon the point in a directly perpendicular plane, till they acquire one identical profile. Being next unscrewed, and examined to ascertain the parts of unequal thickness round the nib, the blades are laid separately upon their backs on the stone, and rubbed down at the points, till they be brought up to an edge of equal fineness. Being screwed together again, it is well to pass them once or twice more, perpendicularly, to bring up any fault; and to retouch them also on the outer and inner side of the blade, to remove barbs that might arise; for which last purpose, too, they should be drawn across the palm of the hand.

To keep the blades of his *inkers* clean while using them, is the first duty of a draughtsman who is to make a good piece of work. To facilitate this, the Indian or Chinese ink, which is commonly used for line drawing, ought to be rubbed down in water to a certain degree—a mean between depth of blackness and consistency—avoiding, on the one hand, conveying a sloppy aspect to the drawing by lightness of shade; and, on the other hand, making the ink just so thick as to run freely from the pen. This medium degree is sometimes ascertained by drawing up the fluid ink on the side of the pallet, and judging of it by the appearance; but a better method is to take up a little of it in a hair pencil after mixing it, and try it on white paper. The shade may thus be correctly ascertained; and experience will lead each for himself to the most proper proportion of ink and water. By rubbing down a stick of ink in water on the pallet, it is apt to crack and break away in splinters at the point. This may be done away by varying, from time to time, the position of the stick while being rubbed, so as to round it away. Nor is it advisable, for the same reason, to bear very hard, as the enamel of the pallet, besides, is subject to wear When the ink, on being rubbed down, is likely to be for some time required, a considerable quantity of it should be prepared, as the water continually vaporises: thereby it will remain for a longer time in a condition fit for application. It is convenient, also, to use two hair pencils, fixed on the ends of a slip of wood—one of them a water brush, and the other for lifting the ink into the pen; which is a much better process than the awkward manner of wetting the pen in the mouth, and then levelling it in the ink; and besides, in using a brush, the ink may be remixed on each occasion, as it is liable to deposit a sediment.

Pieces of unsized paper, and some such stuff as cotton velvet, ought always to be at hand while a drawing is being inked. The former article, when a small piece is folded twice, so as to present a corner, is necessary for passing between the blades of the pen now and then, as the ink is apt to deposit at the point and obstruct the passage, for which purpose the pen must be unscrewed to admit the paper. But the necessity for this may be delayed by drawing the point of the pen over a cushion of velvet, or even over the surface of the blotting-paper; either method clears away the point for a time. As soon as any obstruction takes place, the pen should be immediately cleaned, as the trouble thereby taken will always expedite and improve the work. If the pen should be laid down for any short time with the ink in it, it should be unscrewed to keep the points separate, and so prevent deposit; and when done with altogether for the occasion, it ought to be thoroughly cleaned at the nibs with blotting-paper. This will preserve its edges, and prevent it from rusting.

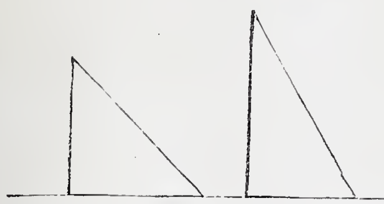
In using the square, it is more convenient to draw the lines off the left edge, with the right hand, holding the stock steadily

but not very tightly, against the edge of the board, with the left hand; the convenience of the left edge for drawing from, is obvious from our being able to use the arm more freely, and because we see exactly what we are doing.

The edges of the square blade ought to be very slightly rounded, as the pen will thereby work the more freely. It is a mistake to chamfer the edges, that is, to plane them away to a very thin edge, with the view of ensuring the correct position of the lines, for the pen is liable to catch the edge and to leave ink upon it. To prevent the latter inconvenience at any time, the outsides of the blades of the pen should be cleaned after each application of the ink.

Very useful appendages to the square are a pair of small

Fig. 4. *Fig. 5.*



right-angled isosceles triangles, like fig. 4, a triangle of 60 and 30 degrees, fig. 5, and a short straight edge. The angles at both ends of the hypotenuse, fig. 4, are 45°, which renders the slant side very serviceable for laying off square figures and other uses; the vertical side, too, saves a deal of shifting of the square, as when the horizontal edge is applied to that of the square, short perpendicular lines may be at once described. The most convenient size for general use is from 3½ to 4 inches of a side. By applying either edge of the triangle, fig. 5, to the square, the slant side gives at once the boundaries of all triangular and hexagonal figures, as nuts and bolt-heads, and also the centre lines of wheels, &c., of six arms.

One-half of the stock of the square is sometimes made loose, so as to turn upon a brass swivel to any angle with the blade, and be fixed down by a screwed nut and washer. This modification is often useful for drawing parallel lines obliquely to the edges of the boards, such as the threads of screws, oblique columns and connecting-rods of steam-engines.

Parallel rulers also are frequently used for drawing oblique lines. We have no great opinion of them, except for sketching jobs, as they are at best inconvenient for working, and liable to derangement in the joints if they be not cautiously used. A much more convenient and accurate method of drawing oblique parallel lines is had by using the isosceles triangles. One of

Fig. 6.

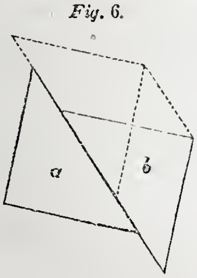
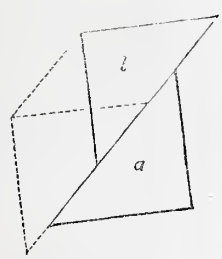


Fig 7.



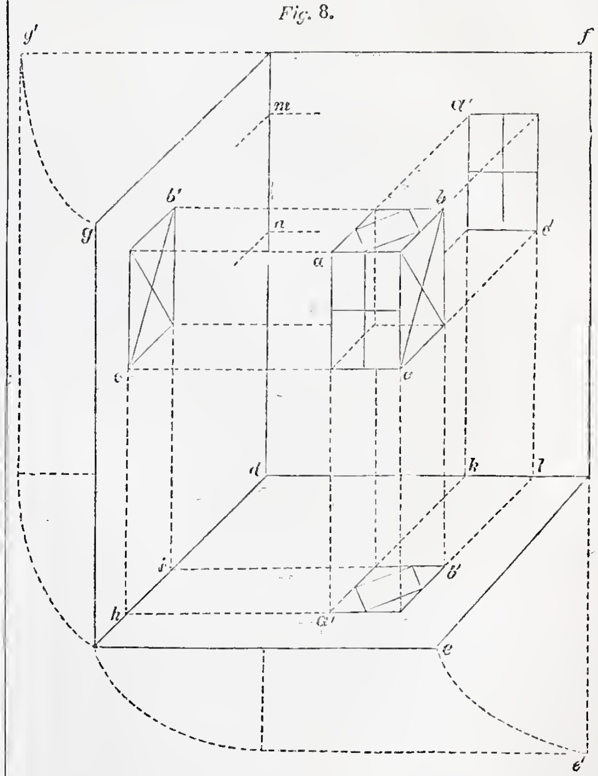
them a, fig. 6, being held down upon the paper with the left hand, the other piece b is applied to it, slant sides together, and by sliding it upon a, it is evident that both its horizontal and vertical edges will move parallel to themselves. Here we find another convenience in the use of these triangles, for by them we may draw lines at right angles to each other, a being kept in one position. For this case the position in fig. 7 is more convenient, as the vertical edge of b is now to the left side.

For the drawing of curves of large radii, which are beyond the range of the compasses, thin slips of wood, termed sweeps, are employed, of which one edge is cut to the required circle. In some cases "universal sweeps" are made, having a centre of variable curvature, which may be applied to the description of curves within a considerable range.

For cleaning up a drawing, a piece of bread two days old is preferable to rubber, as it cleans the surface well, while it does not injure it. When ink lines, to any extent, have to be erased, a small piece of damped soft sponge may be rubbed over them till they disappear. As, however, this process is apt to discolour the paper, the sponge must be passed through clean water, and applied again to take up the straggling ink.

The drawing paper may be fixed down on the board, either by damping and glueing its edges, or by simply fixing it at the corners with pins. The latter method is sufficient where no shading or colouring is to be applied, and if the sheet is not too long upon the board. It has the advantage, besides, of preserving to the paper its natural quality of surface. It is convenient otherwise, however, to lay the sheet with glue, for drawings of any elaboracy, and especially for coloured drawings. It is done in the following way:—Provide a board a little larger both ways than the paper; lay the sheet on the board, with that side undermost which is intended to be drawn upon; come easily, but rapidly, over the upper side with a wet sponge, damping the entire surface, and allow the sheet to lie for five minutes, till it be damped through. The damping ought to be done as lightly as possible, as the sponge will always deprive the paper more or less of its size. The sheet is then turned and set fair with the edges of the board; the square is applied and set a little within one edge of the paper, which is then turned up over the square,

Fig. 8.



and touched all along with the melted glue. It is then folded back and pressed down by the square, after which the edge of a paper-folder, or other smooth article, is rubbed along the "lap," to press out the superfluous glue. The same operation being applied to the other edges, the sheet is allowed to dry, in the course of which it becomes quite flat and tense. Sometimes, in lieu of melted glue, a cake of the same is dipped in water and rubbed upon the board.

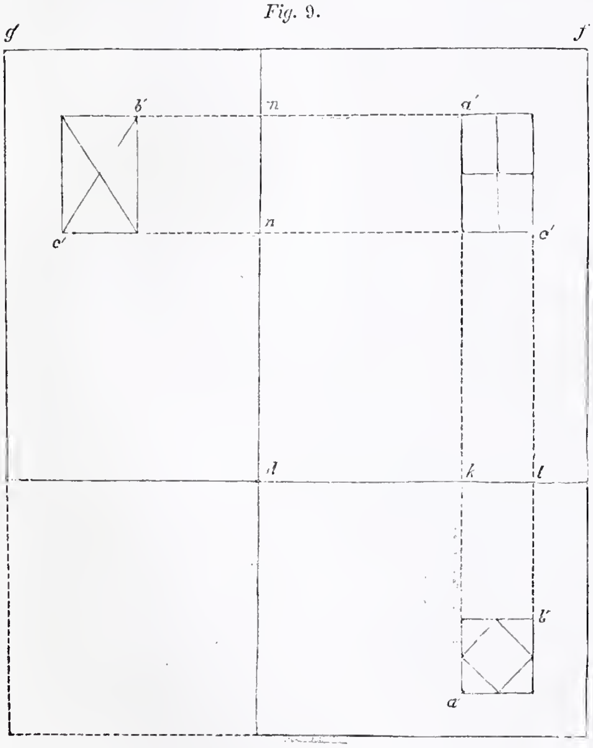
Mechanical drawing is a particular application of the general method of drawing by projection. The special object of mechanical drawing is to represent mechanical forms upon plane surfaces. Every machine, like other collections of matter, has three dimensions, length, breadth, and thickness, which are susceptible of exact definition. Now in viewing a machine from a great distance, we may conceive the rays of light proceeding

from it to move parallel to one another; and conceiving them intercepted upon a plain surface at right angles to the rays, the representation thus formed is said to be a projection of the machine upon that plane; and it is evident that the picture or drawing so formed will convey, so far as it goes, correct ideas of the structure and shape of the machine. But as the form of machines must be referred, in virtue of their bulk, to three series of dimensions, each of them at right angles to the plane of the other, it follows, that any three contiguous planes of a cubical space will answer as planes of projection corresponding to the three dimensions. And there is a felicitous circumstance relative to this, that the dimensions of the component parts of machines in general are disposed in right angles; from which it follows, that if the planes of the projections of a machine be made to coincide with those of its dimensions, then, in general, these dimensions will be exactly indicated. There will, in plainer language, be little of that foreshortening of form which so frequently occurs in representations of natural objects, clearly owing to their wavy and ungeometrical outline.

To illustrate the subject of geometrical projection, let us take for example a parallelopiped of which the outlines are in *bona fide* planes, meeting at right angles

Let $a\,b\,c$ (fig. 8) be a parallelopiped in an upright position, of which the plane $a\,b$ is horizontal, and the planes $a\ c$, $c\ b$, vertical. Let $d\,e$, $d\,f$, $d\,g$, be the boundary planes of a cubical space, in which the body $a\,b\,c$ is placed. Then the sides of the body being parallel to those planes, each to each, let the figure of the parallelopiped be projected upon those planes; for which purpose draw parallel lines from the body perpendicular to the planes, as indicated by the dot lines, and there results the projection $a'\ c'$, upon the plane $d\,f$, representing the surface $a\ c$; $b'\ c'$ on the plane $d\,g$, being the surface $b\ c$; and $a'\,b'$ on the plane $d\,e$, showing the upper surface $a\ b$. As here represented, the projection $a'\ c'$ is denominated a front elevation of the body, representing the front aspect, the projection $b'\ c'$ in like manner, is termed a side elevation, and the projection $a'\ b'$, a plan of the figure. The line $d\ l$ is termed the *ground line.*

Fig. 9.



Here then, we have three distinct views of the regular body $a\,b\,c$, depicted upon plane surfaces, which convey an accurate and sufficient idea of its form. Indeed, any two of these representations are sufficient to describe the body. Take the figures $a'\ c'$, $b'\ c$, for example, to combine the figure $a'\ b'$ from these two, we have only to draw the vertical lines $c'\,h$, $b'\,i$, and $a'\ k$, $c'\ l$ to meet the plane $d\ e$, and produce them horizontally till they meet and form the figure $a'\ b'$; or again, to find the figure $b'\ c'$ from the other two alone, the same lines h, i, are drawn from a', b', and the lines $m\ n$ from $a'\ c'$.

It is exactly upon this principle that a third view of any piece of machinery is to be found from two given views. It is evident, also, that in many instances, two elevations, or one elevation and plan, are sufficient to give a distinct idea of a machine; though it is obvious, at the same time, that frequently many parts are liable to be hid from the view by others in which they are enclosed and by parts in the foreground, in reference to a particular projection. This suggests the occasional necessity, not only of three projections, but also of imaginary views of the interior of a machine, in which the machine is supposed to be cut across by planes either vertical, or horizontal. Such views are termed *sections* of a machine, and in allusion to the *planes of section*, are denominated *vertical* and *horizontal sections.* To all such drawings, we give the general title of *geometrical drawings*, as distinctive from natural or perspective drawings.

By the aid of drawing instruments, measurements are transferable from one position to another. There is no necessity, therefore, for erecting three such planes as we have supposed in our illustration, fig. 8, upon which to execute drawings of a machine. In practice, they are done upon one common surface, and it is easy to suppose the plane $d\,g$ moved back into the position $d\,g'$, and $d\,e$ also moved to $d\,e'$, both these positions being in the plane $d\,f$. This being done, we have the three views depicted on one plane surface, as represented by fig. 9.

In this figure, the same letters of reference are employed as in fig. 8. $d\ l$ and $d\ m$ are the ground and vertical line preserved here, to note the distinction of the planes upon which the figures on both sides of them are constructed, though they are usually omitted. It is evident that the positions of the same points in $a'\ c'$ and $a'\ b'$ are in the same perpendicular from the ground line; that, in short, the position of a point in the plan may be found by applying the edge of the square to the same point in the elevation. The same remark is applicable to the two elevations. Hence the method of drawing several views of one machine upon the same surface of paper in strict correspondence to each other.

The learner will be greatly assisted in forming his conceptions of the meaning of geometrical drawings, by minutely comparing one or two detailed examples with the machines themselves, which they are meant to represent.

THE PRESSURE AND DENSITY OF STEAM.

By William Pole, Assoc. Inst. C.E.

(From the Minutes of Transactions of the Institution of Civil Engineers.)

The relations between the elasticity, temperature, and density of steam, have long been interesting and important subjects of philosophical research.

The connection of the two former, namely, pressure and temperature, with each other, has excited the greatest attention, numerous experiments having been undertaken to ascertain the values of them at all points of the scale, and many formulæ proposed by English and foreign mathematicians, to express approximately the relation between them.

The pressure and temperature being known, the density, or what answers the same purpose, the relative volume, compared with the water which has produced it, may be deduced by a combination of the laws of Boyle* and Gay-Lussac;† and may be expressed algebraically in terms of the pressure and temperature combined; whence, by eliminating the latter, by means of the before-mentioned formulæ, expressions can be arrived at which will connect at once the volume with the pressure.

But there are several difficulties in the way of this process, the equations which may be thus obtained being too complicated for practical use; and, therefore, since it is important in calculations connected with steam and the steam-engine, to find a tolerably

* That "if the temperature remain constant, the density varies directly as the pressure."

† That "if the pressure remain constant, and the temperature change, the volume receives a certain definite amount of augmentation for each degree of temperature added, or *vice versa*." This augmentation is = ·00208 of the volume at the freezing point, for each degree of Fahrenheit, or 00375 for each degree Centigrade.

accurate, and, at the same time, simple rule, which shall give the pressure and volume directly in terms of each other, the empirical method has been resorted to.

The paper enumerates three formulæ given for this purpose by M. Navier and M. de Pambour, explaining the peculiar cases to which they are applicable, and those in which they fail; and the author then proposes a fourth expression, which is intended to meet a case not provided for by either of the others, namely, for "condensing engines working with high-pressure steam expansively;" such as the Cornish, and Woolf's double-cylinder engine. The equation is,—

$$P = \frac{24250}{V - 65},$$

$$\text{or reciprocally, } V = \frac{24250}{P} + 65;$$

P being the total pressure of the steam in lbs. per square inch, and V its relative volume, compared with that of its constituent water.

These formulæ may be adopted without considerable error, throughout the range generally required in such engines, viz., from about 5 lbs. to 65 lbs. per square inch.

Two tables are then given, showing the pressures and volumes as calculated for every 5 lbs. pressure in this scale; they show a comparison of the results of the four formulæ with each other, and the respective amount of deviation from truth in each.

The greatest error is—

	lbs.	
By M. Navier's formula,	1·31	per square inch.
M. de Pambour's first ditto,	4·12	"
" second ditto,	2·75	"
The new formula,	0·71	"

The mean error is—

By M. Navier's formula,	0·245	per square inch.
M. de Pambour's first ditto,	1·42	"
" second ditto,	0·32	"
The new formula,	0·0062	"

The tables also show—

1st. That the new formula is nearer the truth than either of the others taken separately, in three-fourths of the scale.

2d. That it is nearer than all three combined, in half the scale.

3d. That the greatest error of the new formula, with regard to the pressures, is only about half as great as that of the most correct of the other three.

4th. That the mean error is only one-fortieth of either of the others, and only equal to about one-tenth of an ounce per square inch.

5th. That the errors in the volumes are much less numerous and important with the new formula than with either of the others.

It is also added, that the new expression is simpler in algebraical form than the others; it is more easily calculated, the constants are easier to remember, and that no alteration of the constants in the other formulæ will make them coincide so nearly with the truth as the new one does.

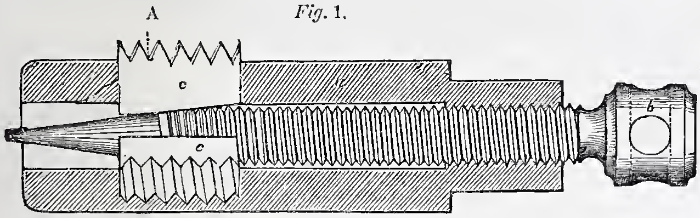
IMPROVED EXPANDING TOOLS.

By Mr. John Yuile, Engineer, Glasgow.

I. *Expanding Tap.*—The superiority of this form of tap over those of the ordinary form, has been acknowledged by the Royal Scottish Society of Arts, who awarded to Mr. Yuile, for the contrivance, one of the Society's honorary medals, of the value of five sovereigns.

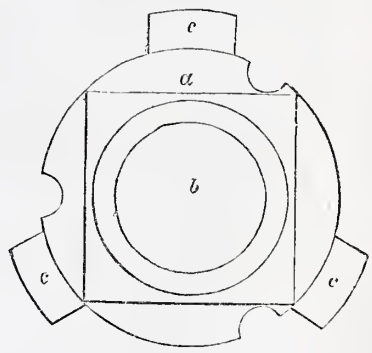
Fig. 1 is a longitudinal section of the tap; fig. 2 is an end

Fig. 1.



Expanding Tap—longitudinal section, with dies projected in their places.

Fig. 2

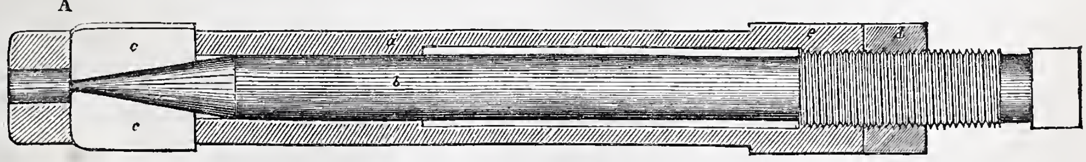


End View—enlarged scale.

view of the same; and fig. 3 a cross section in the plane, A, of fig. 1. The tap is composed of three principal parts—the barrel, the pin, and the dies. The barrel, *a*, which is cylindrical, is squared down at the upper end, to receive a wrench for working it. It is hollow throughout, being screwed at the upper end to receive the pin, *b*, which is also screwed. This pin is conically tapered at the under end, by which it is enabled, when screwed down, so to act upon the dies, *c*, as to press them gradually outwards from the centre. The dies, three in number, are inserted in slots cut in the barrel, in which they fit exactly, and may also be moved freely outwards by the action of the cone which terminates the pin. To assist this action, they are bevelled on the inner surface to the same taper as the cone, which will thereby act upon them steadily and equally.—Figs. 1, 4, and 7, are drawn to half the scale of the others.

The process of screwing nuts by this tap is as follows: The

Fig. 4.



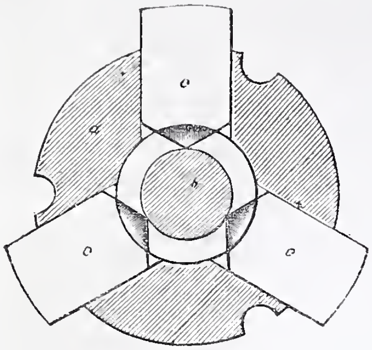
Expanding Drill—longitudinal section.

nut having been forged to allow the end of the barrel to pass through it, the pin is so far screwed back as to allow the dies to meet in the centre; the barrel being then passed into the nut till the dies are half covered, the latter are pressed outwards by the pin, upon the interior of the nut. Having thus gained a hold, the barrel is turned round continually, till the dies have gone half through on the other side of the nut. The initial thread which they have thus cut, guides them afterwards in retracing their course, which is effected by returning the tap, after pressing out the dies a second time. These alternate

steps having been continued till the thread of the nut is, by successive cuts, completely formed, the tap is disengaged and withdrawn.

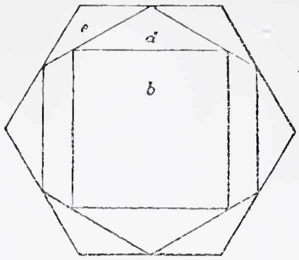
The advantages of this tap, in comparison with ordinary taps, are evident:—First, the whole business is done with one tap, superseding the necessity for distinct taper and barrel taps; secondly, the operation is transformed from a crushing action in forming the thread, by the ordinary tap, into a simple and easy cut by means of the dies, and we thereby remove the labour of wrenching the tap, and the risk of fracturing; thirdly, in the

Fig. 3.



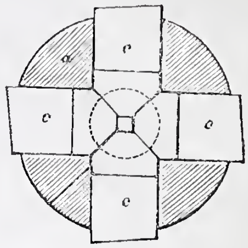
Cross Section of Tap at A, fig. 1.

Fig. 5.



End View of Drill.

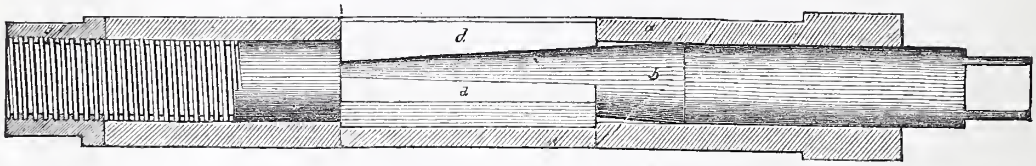
Fig. 6.



Cross Section of Drill at A, fig. 4.

same barrel, sets of dies having variously-formed threads, and of various pitches, may be inserted for various kinds of nut; and even dies may be inserted in the same barrel for several different diameters of nut—as, for example, a regular two inch tap may cut nuts of from 2 to 2⅜ diameter, and it is evident, too, that a nut may be nicely fitted to any given external screw. In large cast-iron nuts, it forms a very excellent thread, which might recommend nuts of that metal for several purposes.

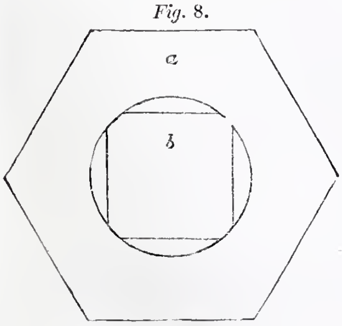
A *Fig.* 7.



Expanding Mandril—longitudinal section, with dies projected in their places.

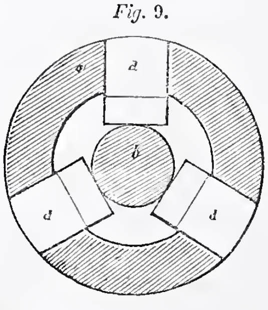
II. *Expanding Drill.*—The drill is made on the same principle as the tap. Figs. 4, 5, 6, represent its longitudinal section, end view, and cross section, at A of fig. 4. *a* is the barrel, which is hollow throughout, being screwed at the neck to receive the pin, *b*, and bored near the other end to guide it. At the same end, four dies, *c*, are inserted in apertures made for them, and are acted on by the conical end of the pin; *d* is a jam nut upon the pin to maintain it securely fixed; *e* is a six-sided

Fig. 8.



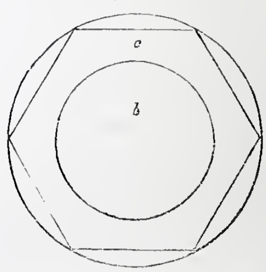
End View of Mandril at top.

Fig. 9.



Cross Section of Mandril at A, fig. 7.

Fig. 10.



End View of Mandril at bottom.

portion of the barrel, by which it may be prevented from turning during the process of boring.

On using this instrument, its cutters are set by the conical point to the diameter of bore required, and the jam-nut screwed up. It is entered and driven like an ordinary drill.

Its advantages are peculiar: for, first, we may, by its use, bore an unlimited number of holes of exactly one diameter, as the cutters may always be taken out, sharpened, and replaced with accuracy. A great difficulty is thereby overcome; as, with our usual plate-drill and cutter-block, it is a matter of trouble and uncertainty to finish two bores precisely alike. Secondly, it combines in itself, and by reason of its adaptive quality, the use of many distinct drills of an ordinary kind, and will therefore materially diminish the number of stock pieces.

III. *Expanding Mandril.*—In this instrument the coniform portion of the spindle is set in the middle of the pin, and the screwed part is removed to the other end. Figs. 7, 8, 9, are a longitudinal section, and two end views of the mandril; and fig. 10 is a cross section at A; *a*, in fig. 7, is the barrel, hollow throughout, and formed with a triagonal end; *b* is the pin, bearing in the barrel at both ends; it is cut with a square thread screw, which wears a nut, *c*. The dies or wedges, *d*, three in number, are inserted at the middle of its length.

This mandril is easily applied; being passed through the hole in which it is meant to be fixed, and the wedges being, of course, within the hole, the nut is screwed up, till, by bringing down the coniform portion of the pin, the wedges are jammed into the hole. This being done, the whole is ready for being set in the lathe.

Here the same advantage recurs that we found for the drill. A few of these mandrils would suffice for a whole establishment, as each one can be adapted to holes of a considerable range of diameter. Further, a vast amount of time and labour consumed in fitting ordinary mandrils is economised by this simple instrument; in many instances, the former articles require more time for the mere turning and fitting of them, than the objects for which they are prepared.

FLAX,

AND THE PROCESSES OF ITS MANUFACTURE.

CHAPTER III.

SPINNING, WEAVING, AND BLEACHING (CONTINUED)—CHEVALIER CLAUSSEN'S PROCESSES.

We concluded our last paper on this subject with some remarks on the spinning and weaving of the yarn, the methods of computing its fineness, the manner in which it is made up for the market, and other arrangements adopted in the large spinning-mills of the country. It may here be observed, that the employment of machinery in spinning flax may be considered as the salvation of the Irish linen trade. Had Ireland continued to maintain hand-spinning, it would have been impossible for her to contend with other manufacturing countries in the great markets of the world. The comparative cheapness of mill-spun yarns, and their superiority in the production of an even and uniform fabric, form the basis of the present condition of the linen trade. Formerly, it was impossible for the linen merchant to assort his parcels properly, from the great variety of yarns employed in the manufacture, and from their unevenness of quality. Now, large parcels of linen can be made to order, to any degree of fineness, heavy or light, as may be required. The manufacturer buys his yarns in quantities of the spinner, and gives them out to his weavers, so that when he receives the linens from them they are as nearly as possible of the same quality and appearance; they bleach regularly, and when exported are always the same as the sample.

Linens are no longer sold to any extent in the open market by individual weavers. A new system has arisen. There are now in Ireland, manufacturers, many of whom employ from 100 to 2,000 and 3,000 weavers, and who purchase the yarn in quantities, boil it, wind it, and give it out to be woven, receiving the webs on certain appointed days, and paying the weaver for his labour by the piece. There are, however, some extensive firms who are at the same time both spinners and manufacturers, who send their linen to the bleacher, and receive it from him when finished; after which they have it lapped and ornamented, and either export it direct, or sell it for home consumption. These houses make a variety of fabrics, in which they are guided by the demand in the respective markets. As in the case of most other manufactures, certain districts excel in the production of different kinds of fabrics. Thus, the neighbourhood of Lurgan is the seat of the cambric and lawn manufacture; Lisburn and Belfast of damasks; Armagh of light linens; Ballymena of heavy goods; and so on.

BLEACHING.

Before the linen is ready for market, the greater portion of it has to undergo the process of bleaching, the sale of brown or unbleached goods having considerably diminished of late years. This process constitutes quite a separate department in the trade, the bleacher in most cases having the goods from the manufacturer, and returning them again to him when finished and ready for sale. In this department, great advances have been made during the present century. Formerly, "butter-milk" was supposed to possess peculiar bleaching properties, the lactic acid it contained being probably the active agent; consequently, a large herd of cows was a necessary appendage to a bleach-green. In 1764, Dr. Ferguson, of Belfast, received from the Linen Board a premium of £300, for the successful application of lime in the process. In 1770, he introduced the use of sulphuric acid; in 1778, potash was first used; and in 1795, chloride of lime was first practically applied. In those days the bleach-greens were more numerous than they are now, notwithstanding the immense increase in the linen trade. Improved processes, and a better application of labour, enable the bleacher of the present day to turn out nearly ten times the amount of work he could do fifty years ago. The process is commenced by steeping the goods in hot water to dissolve the dressing, and then followed by boiling them in a weak alkaline ley for a certain time. They are then washed in rather a primitive and somewhat expensive manner, after which they undergo a scrubbing process with soap and water, and are then washed again, and carried to the green to be grassed. Here they remain spread out and exposed to the weather so many days, according to the description of the goods. They are then taken in for the last part of the operation—the chlorine process, which requires both care and skill in its application. Chloride of soda is used in preference to chloride of lime, the goods being afterwards immersed in a weak solution of sulphuric acid, and again thoroughly washed. The drying is usually done in heated chambers, whence the goods are taken to the beetling-machines. This operation is the last, and nothing remains but to fold them up into their proper forms, press them, and then they are ready for market. Some very beautiful chemical principles are involved in the bleaching process—the alkali in the boiling solution combines with the greater part of the organic colouring matter of the linen, which is dissolved in the boiler, or in the subsequent washing; the bleaching effect of exposure on the grass to the action of light has long been known, though the cause was until recently but little understood; and the successful application of chlorine belongs quite to the scientific bleacher of the present day. Not only is the operation more perfect, but an important saving in time is effected by the present system, the entire process averaging now from four to six weeks, instead of the six months of the old system. Indeed, the time now is often determined by the market requirements; in the case of an urgent demand, goods have not unfrequently been returned by the bleacher in a week or ten days.

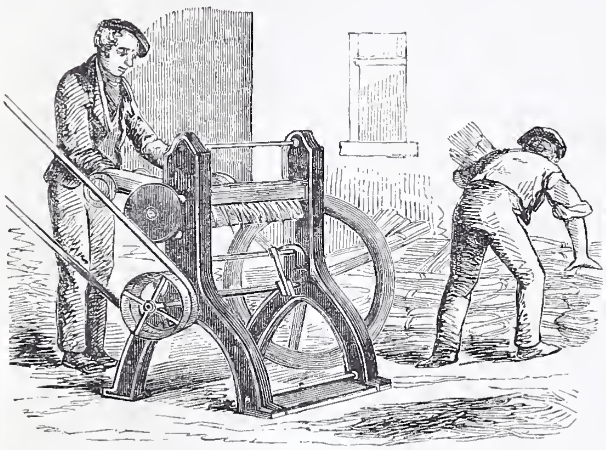
CHEVALIER CLAUSSEN'S PROCESSES.

To complete our account of the flax manufacture, it only remains to describe an important discovery of very recent date, which promises to open up a new market for home-grown flax, and to bring the material into much more general use, by fitting it for mixing with wool and silk, and rendering it capable of being employed to a great extent in the same way as cotton. It appears, at first sight, that this is like "turning gold into lead," as flax, in its present manufactured state, is more costly than cotton; but the raw material is cheaper, and when manufactured, or *cottonized*, by the processes which we are about to describe, it is alleged that the yarn may be sold at a lower price than cotton yarn, and that it will be found superior to the latter for various purposes. The discovery to which we allude is that of Chevalier Claussen, formerly an extensive cotton-grower and slave-owner in the Brazils, who has now erected considerable works at Stepney for carrying out his improved processes on a large scale. This gentleman was led to the idea which has issued in these important results, by a purely fortuitous circumstance. It appears that, while wandering along the luxuriant banks of one of the Brazilian rivers, his attention was attracted to a white down-like substance adhering to the branches of trees overhanging and touching the stream. Naturally thinking that this was some curious vegetable product hitherto unknown, he resolved to trace it to its source, and to ascertain, if possible, the plant which produced it. Eventually he found that the substance had been washed from a bed of his own flax-straw, which, long before, he had caused to be thrown as useless near the banks of the river. As the swollen waters had occasional access to this heap, fermentation, and the decomposition of a portion of the plant, had taken place; and in time, the influence of natural chemistry had so saturated the filaments of the flax fibre as to

give the mass a cotton-like appearance, some of which having been washed away by the river, had been caught by the overhanging branches. The substance thus accidentally discovered, though not in a state which would fit it for the processes of spinning, &c., in the same manner as cotton, suggested to Chevalier Claussen the idea of making experiments upon it, with the view of bringing it to that state by the aid of chemistry. In this he appears to have succeeded beyond his most sanguine anticipations.

Before subjecting the flax, however, to any chemical process, the Chevalier breaks the straw, after rippling, by means of a machine, which is simply a modification of that which was already in use for a similar purpose. This machine is exhibited in operation in fig. 13. It partially separates and

Fig. 13.



removes the fibre, without the preliminary operation of steeping—divesting the flax-straw of three-fourths of its bulk, and thus overcoming a difficulty experienced in the sending to market of any large quantity, while, at the same time, the refuse is applicable for manure, and even as food for cattle. It is true, that the fibres are still partially held together by the gum-resin; but even in this state, without any further preparation, the flax is suitable for strong and coarse fabrics, such as sail-cloth, ropes, cordage, canvas, &c., and may be advantageously applied to many of these uses as a substitute for Russian hemp.

To fit it, however, for the linen manufacturer, and also for the cottonizing process, the fibres must be thoroughly separated by steeping, and here it is that M. Claussen has contributed a most important improvement. The time required by the ordinary process of fermentation was too long, and even when completed by this process, the action was not sufficiently uniform. Claussen, therefore, adopted the plan of boiling the flax, when brought from the "breaker," for four or six hours in a weak solution of caustic soda, or steeping it for twenty-four hours in a cold solution; or for twelve hours when the solution was heated to 150°. Instead of soda, caustic potash or lime may be used; and the result, with a solution of either of these substances, is to entirely remove the resinous matters of the plant, and to render the flax perfectly free from stain and impurity. These preparatory processes are practised by M. Claussen whether the fibre is required to be *long*, for spinning on flax machinery, or subsequently rendered *short*, that it may be felted or carded, and adapted for spinning on cotton, silk, wool, worsted, or tow-spinning machinery. The subsequent processes vary according to the purpose for which the flax is destined.

If the fibre is required to be long, the free alkali adhering to the mass after steeping or boiling, and any remaining gummy matter, are got rid of by washing in water containing one per cent. of sulphuric acid, in which it is immersed for a couple of hours, and then in pure water. It is afterwards passed through the bleaching liquor, and is sometimes exposed to the fumes of burning sulphur while still wet with the bleaching solution, such as hypochloride of lime. When washed and dried, it is now ready for breaking and scutching, as in the ordinary manufacture of long flax. Even in these processes, in which the flax is not cottonized, but simply prepared for ordinary purposes by a new method, we find an immense improvement on the old system. The preparation of the fibre is effected in one day, instead of perhaps a dozen, or even six weeks, the long and difficult process of fermentation being entirely avoided; while, by the new method, it is rendered uniform in strength, and can be bleached and dyed with much less trouble. By this improved and rapid process, twenty per cent. of long flax may be obtained, instead of seventeen, while the substance is far more silky and soft. Even independently, therefore, of his cottonizing process, Claussen has contributed a very important improvement to the flax manufacture.

The *cottonizing* is performed in the following manner:—In the first place, by means of a machine similar to that used in chaff-cutting, the flax is cut into short lengths, corresponding with the staple of cotton. It is then steeped or boiled in the caustic soda vat already described, and from this, after washing, it is removed to another vat, containing a solution of bicarbonate or sesquicarbonate of soda, in which it remains for an hour or two, till fully saturated with the salt. It is then placed in a third vat, in which there is five per cent. of sulphuric acid; and this, combining with the alkaline base of the salt with which the fibre was previously saturated, generates carbonic acid gas, the expansive force of which splits the fibres into a vast number of ribbon-like filaments, exhibiting, under the microscope, very much the appearance of raw cotton. They are thus rendered more flocculent; their specific gravity is completely altered, and they now rise to the top of the vat, while before they sank to the bottom. By the bursting of the hollow cylinders of which the fibres consist, the whole becomes a soft cottony mass, and is now termed flax-cotton. It is then placed in another vat of soda, to neutralize any remaining acid, and from this it is transferred to the bleaching water of a fifth vat, composed of a solution of chloride of lime and sulphate of magnesia. The fibres are perfectly bleached by this mixture in two hours, and are then transferred to a bath of diluted sulphuric acid, and finally washed clean in pure water.

This flax-cotton, when dried, carded, and spun, is found to produce a considerably greater quantity of yarn than that obtained from a similar weight of cotton; and it is so well adapted to cotton machinery, that several large manufacturers have offered to take any quantity that may be supplied to them. Cloth made from the yarn may be readily printed, dyed, and bleached, by the ordinary cotton processes. By the mixture of flax-cotton with wool, it is expected that cloths quite as durable as those made of wool alone, will now be produced, at a price from twenty-five to thirty per cent. lower. It may be spun with silk on the existing silk machinery, and any otherwise useless flax can be converted into a good article for the papermaker.

The following is Chevalier Claussen's own estimate of the price at which flax-cotton can be produced:—"On the average, five tons of flax-straw will produce one ton of British cotton, the cost of which, at £3 per ton, would be £15. The expenses of breaking, cutting, and blowing, will not exceed £1. 19s.; chemical preparations and ingredients employed, £1. 5s. Thus the total cost of one ton of flax fibre, or British cotton, equal to fair quality American cotton, would be £18. 4s. Add to this, when required, for bleaching, £1, and the washing, drying, &c., £1. 16s.; then the total cost of the British cotton, bleached and washed, would be £21 per ton, or 2¼d. per lb., and which will readily sell at from 4d. to 6d. per lb." The average price of foreign cotton at Liverpool, is 5d. to 6½d. per lb.

The correctness of M. Claussen's estimate only requires to be tested on a large scale. If it proves to be correct when so tested, there is no doubt that the cultivation of flax will soon be vastly extended in this country, and that it must supersede, to a great extent, the use of American and East India cotton in many descriptions of our textile manufactures.

It has been objected, indeed, to the cottonizing process, and even to the preparation of the long fibre by M. Claussen's method, that the flax fibre is materially injured by the chemical agents, and that, when so prepared, the yarns and fabrics manufactured from it are deficient in strength, and are much inferior in quality. In answer to this objection, Claussen maintains it to be impossible that one part of soda in 200 of water, and one part of sulphuric acid in 500 of water, can injure the most delicate fabric—more especially as the acid and alkali are speedily brought into contact, and neutralise each other. It may be remarked, indeed, that the process of bleaching by chlorine, which is now universally practised, was met with precisely the same objection when first introduced into this country by Mr. Charles Tennant. This question, however, as well as that of the cost at which flax-cotton can really be produced and manufactured, on a large scale, will soon be completely set at rest by experiments now in progress.

In our next and concluding chapter on this subject, we shall give a short account of the history and statistics of the flax manufacture, with special reference to Ireland.

HORTICULTURE.

CHAPTER IV.

PROPAGATING, PLANTING, TRAINING, AND GENERAL MANAGEMENT OF FRUIT TREES.

The natural manner of propagating vegetables is undoubtedly by sowing the ripened seed. But there is a practical objection to increasing our fruit trees in this manner. All the varieties of apples are modifications of the wild crab, and the varieties of pears, and of the other cultivated fruits, of other equally worthless trees. Besides, in point of fact, all the different examples of a variety are but one individual tree. For example, there are a great many Ribston pippin apple trees, but these are not separate trees, each sprung from a seed, but extended portions of the first-produced Ribston pippin. So many pieces of the original Ribston pippin were grafted into as many young crab plants, and each of these grew into a large Ribston pippin tree; pieces were taken from these and grafted on other crabs, and so on.

We must look, then, upon all the samples of each different variety of cultivated apple, for instance, as forming only so many individuals of a modified crab. Now, the seed of any variety, when sown, has a tendency to produce a plant like the original crab; and the same is true of all the other fruits. We have a practical instance of the truth of all this in what has happened in America. The stones of the finest peaches have been sown on a large scale there, but most of the trees thus produced are so worthless, that the peaches they bear are only fit for feeding pigs, and are, in fact, appropriated to that use. Still, by proper management, good kinds may be raised from seed; and, indeed, although propagating fruit trees in this manner will never be the common plan, it is probably essentially necessary to do so for the following purpose.

Assuming that all the examples of any variety of fruit tree be, in reality, but one individual, and recollecting that all individual plants end in death, it is clear that there is a chance, or rather a certainty, that every one of our existing varieties may die out. And, in fact, some of the most admired cider apples of the seventeenth century have so died out, and a great many more are evidently fast decaying away. In order to keep up the number of varieties of fruit trees, it was proposed by Mr. Knight, who first directed attention to the subject, to obtain fresh varieties by means of seeds. He was quite successful; but the attention and care necessary for success is far too great for an ordinarily situated individual to take. We therefore pass on to the usual and simpler mode of propagating fruit trees.

Gooseberries, currants, sometimes codling apples, and also many trees and herbaceous plants, are propagated by means of *cuttings*, as they are called. These consist of annual shoots, with a thin skin of last year's wood, taken from the parent plant. It is believed that cuttings should be taken from that part of the parent nearest the ground, and from the side shoots, rather than from the summit or main branch. The eyes or buds nearest the cut end are removed, and the cutting then placed firmly in the soil.

Some very curious practical anomalies exist regarding cuttings of some plants, which it may be interesting to state. The cuttings of some sorts of trees, as, for instance, of orange trees, will not take root if planted at the middle of a flowerpot, but will if planted at the edges. Cuttings of mulberries will not strike unless the lower end touch some gravel or broken pots; and other equally unaccountable instances might be adduced.

The proper time for making cuttings, of deciduous trees at least, is the winter.

Propagating by *layers* is that modification of propagating by means of cuttings, in which, for a while at first, the cutting is allowed to retain its connection with the parent plant. The season for making layers is the spring, when the sap is about to begin to flow. In order to make layers, a branch is bent to the earth, and pinned there with pegs. A few inches from the end a slit is made, beginning generally from a bud, and the whole branch, except a few buds at the extremity, is covered with soil. The layer is generally fit to be removed from the parent in the autumn, but sometimes it requires to be allowed to remain attached until the autumn but one after.

Propagating by *grafting* is the commonest mode of increasing the number of our fruit trees, and almost the exclusive one of apple and pear trees. It consists in inserting the shoot or young branch of the tree intended to be grown, into the stem or the branch of another. This latter is called the stock, and the shoot or young branch, the scion.

It is absolutely indispensable that the stock should be of the same genus as the scion, or, at any rate, of very close affinity to it; and experience has proved that the best kind of stocks are * —

a. For apples.
- The Crab apple, (raised from seed.)
- Paradise apple, (layers.)
- Crofting do.
- Bur-knot apple, (cuttings.)

b. For pears.
- Common pear, (seedling.)
- Wilding pear, do.
- Quince, (seedling or layer.)

c. For plums.
- Brussels plum, (seedling.)
- Brompton plum, do.
- Bullace plum, do.

d. For cherries.
- Gean, (seedling.)

e. For apricots.
- Wilding apricot, (seedling.)
- Muscle plum.
- Brussels plum.

f. For peaches and nectarines.
- Muscle plum.
- Pear plum.
- Damas noir plum.
- Almond.
- Wilding peach.

Some of these are selected according as it is wished to have dwarf or large trees. Thus, for dwarf apples, the paradise itself is the one usually selected; the quince for dwarf pears, and the bullace for plums.

The proper time for sowing seeds for seedling stocks, is the month of March. They are sown in beds, and transplanted the following year to where they are to remain until they attain their sufficient size.

Invariably the scion is a portion of the wood of the preceding year of the tree from which it is removed. If the variety to which the scion belongs is a bad bearer, it is said to be

* Neill.

advisable to take the scion from a bough that is more remarkable than the rest for its fertility. The time for affixing the scion to the stock is March. The great point to be attended to, is to see that the inner bark of scion and stock exactly correspond: if they do not, of course the sap cannot circulate. After closely fitting the two, they are secured in their places by means of bands of matting, and over all a quantity of ductile clay is besmeared.

Several modes of shaping the extremities of the stock and scion are in use. The following abridged extract from Neill adverts to most of them:—"The most usual mode of grafting is called *whip grafting*, or tongue grafting. The top of the stock and the base of the scion are cut off obliquely, at corresponding angles, as nearly as can be guessed by the eye; the top of the stock is then cut off horizontally; next a slit is made downwards in the centre of the sloping face of the stock, and a corresponding slit upwards in the corresponding face of the scion. The tongue, or upper part of this sloping base, is then inserted into the cleft of the scion, and so adjusted that the inner bark may unite neatly and exactly on one side. The junction is then tied up and covered with clay. Several other methods may be mentioned, such as cleft grafting, in which the scion is sloped at the base, and inserted like a wedge into a cleft in the stock. Side grafting resembles whip grafting, but is performed on the side of the stock without heading it down. Crown grafting is performed by inserting the scions between the bark and the wood of the stock." There is also grafting by approach, or manching, which, according to the same authority, resembles whip grafting, "but the scion remains attached to the parent plant till its union with the new stock be complete."

Another mode of propagating fruit trees is by means of what is called *budding*, and this plan is the one usually followed when we wish to increase peaches, nectarines, and apricots. In it we have stocks and scions, and the stocks are those previously enumerated. Instead of a scion, however, a bud is taken from the bark of a tree of the desired kind, taking care to leave a small piece of bark attached to it, and this is inserted into the bark of the stock, and kept there by means of matting. The right time for performing this operation is the month of August; in about a month after doing it, the ligature may be removed. By next spring a sprout will be thrown out, and of course all the other sprouts of the stock must be carefully kept down.

Next to the propagation of fruit trees, comes the important subject of planting them. If the subsoil is bad, it is essential to prevent their roots getting at it by mechanical means. On inspecting many monastic gardens, we can find evidence that this was done by their cultivators, by means of large flags placed underneath the roots. It is now considered sufficient to form an impervious bottom with lime rubbish, coal ashes, clay, gravel, &c. Perhaps, when the land has been well drained and trenched, there is no occasion to do anything. The season for planting is either early winter or spring, and preferably the former. The young trees must be carefully taken from the nursery, due care being had that their roots are not injured. Holes must be dug in the spot of ground intended to receive them, and when they are put into these, their rootlets are spread out and mixed amongst the soil. If they are wall trees, about six inches must be allowed to intervene between the place in which they are fixed and the wall, to allow room for the stem to enlarge. If they are intended to be standard trees, they must have a strong stake firmly driven into the ground by their side, to which they must be securely attached, to prevent the shaking of the stem by the winds breaking the rootlets. On filling up the hole, besides as much earth as was taken out of it to form it, as much more manure must be mixed with it, and heaped up around the young root and lower part of the stem. If the weather is dry, they must be watered.

The peaches, nectarines, and apricots, must be planted against the wall facing the south. So must the more delicate pears, and the earliest cherries. So, likewise, must any particular tree that it is desired should bring its fruit early towards maturity. The later cherries, the remainder of the pears, the plums, the apples, the currants, &c., should occupy the walls with the aspect to the east and west. Upon the wall facing the north should be placed Morelle cherries and currant bushes.

It is not usual, in the northern part, at least, of the island, to plant anything but apples and pears on the espalier rails, and scarcely as dwarf standards; and even then it is common to select the hardier varieties.

The wall trees intended to be permanent are all grafted near the ground, and are called by the gardeners, dwarfs. The peach dwarfs are planted about sixteen feet apart, apricots a little wider, plums and cherries about the same, pear trees about twenty feet, and apples from fifteen to twenty. The apples and pears on the espalier rails are put at from fifteen to twenty feet distant.

In forming a new garden, it is clear that, if the fruit trees be planted at this distance, the greater part of the wall will be for years useless. The best plan of obviating this, is to plant between every two, temporary trees, that have been grafted on pretty tall stocks. These are called *riders*.

With regard to the training of trees, we may observe, that the gardener, in performing it, has two objects in view. The one simply refers to the form of the tree, and may be considered as training proper; and the other has for its end the regulation of the bearing wood, and consequently of the blossom and the produce, and is often called pruning.

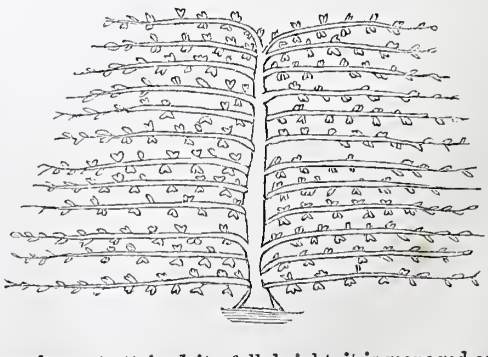
The training of tall standards is a very simple business, and mainly consists, when two branches cross or rub against one another, in cutting one away. Dwarf standards receive a little more attention. They are usually allowed to grow in the form of a bush, but pear trees are now compelled to assume the form shown in fig. 1.

Fig. 1.

The trees upon the espalier rails are sometimes allowed to have two stems, sometimes only one. In either case, the stem is upright, and branches are led from it on either side along the rails. In summer it is necessary to keep down the upright shoots, which espalier trees have a strong tendency to put out. This is done by rubbing out the buds as fast as they appear.

Training wall trees is a more complicated business: two forms of doing it, the horizontal and the fan, are in use in this country. Of these, the former, as shown in fig. 2, is the most frequent. In it there is one perpendicular stem, which ascends the whole height, and the branches proceed at right angles from it, at intervals of about ten inches. As long as

Fig. 2.

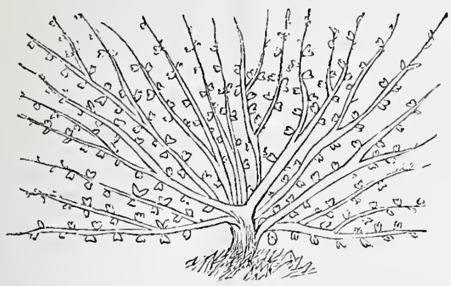


the tree has not attained its full height, it is managed as follows:—Every winter the vertical shoot is cut back to within fourteen inches of the highest pair of branches: in the beginning of summer, a number of shoots will be produced; three

of these are selected, one is trained in the original direction of the stem, and one on each side of it, parallel with the ground. At midsummer, the point of the leading shoot is pinched, and this affords another pair of horizontal branches. In this manner, two side shoots are obtained every year on each side. When the tree has reached the top of the wall, it is only allowed to increase in breadth.

The fan mode of training (fig. 3) is occasionally used for apples and pears, and pretty generally for stone fruit trees,

Fig. 3.



although, for the latter, the modification of it shown in fig. 4 is employed. Both kinds consist in having no leading stem, and having their branches spread out something like the spokes

Fig. 4.

of a fan. The difference between fig. 3 and fig. 4 is, that in the latter are certain number of mother branches, each of which sends off a number of subordinate ones; while, in the former, all the branches are equal, and arise from a common centre.

The late Mr. Smith, gardener at Hopeton House, introduced a modification of fan and horizontal training, which perhaps possesses the advantages of both kinds. He has a leading stem, but the branches come off, not at a right, but an acute angle.

The above remarks may serve as a general account of training. We proceed to describe the more important particulars regarding each separate kind of fruit tree, and the pruning of them.

We begin with the peach. Its fruit is produced on the twiggy shoots of the previous year. "If," says Neill, "these be too luxuriant, they yield nothing but leaves; and if too weak, they are incapable of maturing the fruit." The object, then, of the pruner is to furnish these in sufficient abundance, and of the requisite strength. The peach is almost uniformly trained in the fan manner. It is said that it is better to begin with a maiden tree, that is, a tree the first year after it has budded. "It is then headed down to five or six buds, and in the following summer two to four shoots, according to the vigour of the plant, are trained in, the laterals also being thinned out, and properly nailed to the walls. Suppose there be four branches, in the subsequent winter the two central ones are shortened back to produce others, and the inferior ones are laid in nearly at full length. In the following season additional shoots are sent forth, and the process is repeated until eight or ten principal limbs, or mother branches, be obtained, forming, as it were, the framework of the future tree. These mother branches are occasionally raised or depressed, so as to maintain their equilibrium, and are as much encouraged to grow outwards as is consistent with the regular filling up of the tree. The laterals are carefully thinned out (by pinching off with the fingers) in summer, and the remainder are nailed, so as to afford subordinate members and bearing wood. When the centre of the tree has been filled up, all the training necessary is merely to prevent the inferior members from acquiring an undue ascendancy over the mother branches. It is highly advantageous to have abundant space, and to draw the tree outwards, so that it be thin, but nowhere destitute of young shoots.

"Meanwhile the pruning for fruit has been going on. This consists in shortening down the laterals which had been nailed in at the disbudding or summer pruning. Their length will depend on their individual vigour, and the luxuriance of the tree. The buds, which are generally double, or rather, two together with a fruit-bud between them, seldom occur quite close to the insertion of the shoot. Perhaps two or three pairs are left with a wood-bud at the point, to afford a growing shoot, in order to act as its lungs; for it is necessary that there should be leaves above the fruit. The extent of thinning of the fruit must depend on the vigour of the tree, a pair of fruit to each square foot of wall being an average allowance. When the fruit begins to swell, the point of this budding shoot is pinched off, that it may not drain away the sap. Any young shoot from the wood eyes at the base of the bearing branch is carefully preserved, and in the following winter it takes the place of the branch which has borne fruit, and is cut out. If there be no young shoot below, and the bearing branch be short, the shoots at the point of the latter are pruned for fruit; but this must be done cautiously, and if the bearing branch be long, it is better to cut it back for young wood." *

In the northern part of the island, the growth of spurs on the young wood is encouraged. They are produced by leaving, during the summer pruning, a number of the little shoots put out by the yearly wood, and on these spurs blossoms form early in the succeeding season.

Peaches, always a precarious crop in the open air, will be a certain failure unless the trees receive protection at the time of blossoming. The commonest application is branches of spruce or silver fir, woven together in frames, and spread before the tree at night.

Peach trees are liable to mildew, &c.; and to cure this it is recommended that they should be brushed over with a compost of black soap and flower of sulphur, mixed with water, and boiled down to the consistence of paste. This application, if made, ought to be made in winter.

The management of the nectarine is the same as that of the peach.

The apricot is propagated by budding on a plum stock. It is almost always trained in the fan fashion. Its fruit is produced on shoots of the preceding year, and on small close spurs formed on the two-year-old wood. Its management is much the same as that of the peach. It should be pruned in summer and in winter. In the former pruning, all irregular and useless shoots are to be pinched off; and at the latter, the worn-out branches, and those not furnished with spurs, should be cut away.

Although the blossom of the apricot is hardier than that of the peach, yet, in the northern part of the island, it is the better of being protected. If too many apricots set, as is often the case, they must be thinned out in July. These immature apricots make very good tarts.

Plum trees are grown as standards, and all the pruning such require is to have some of their superfluous wood removed when young. The finer kinds are reproduced, or rather increased, by budding. Plum trees produce their fruit "on small natural spurs, rising at the ends and along the sides of the bearing shoots, of one, two, or three years' growth." In most soils, new fruit branches are two years old before the spurs bear. The same branches and spurs continue fruitful in proportion to the time which they take to come into bearing. Plums are trained in both the horizontal and fan plans, and it would seem that there is more authority in favour of

* Neill.

the former plan. Most gardeners think it injurious to shorten fruitful branches, and are of opinion that doing so favours the production of gum.

Sometimes plum blossom is protected.

Cherry trees are grown as standards, as riders, and as dwarfs; in the north, usually against a wall. The best mode of training them is in the fan method; and for the Morelle variety, this fan arrangement is absolutely necessary. Cherry trees, in general, produce their fruit upon small spurs or studs, from half an inch to two inches in length, which proceed from the sides and ends of the two-year, three-year, and older branches; "and as new spurs continue shooting from the extreme parts, it is a maxim, in pruning both standards and wall trees, not to shorten the bearing branches when there is room for their regular extension. The Morello is, in some degree, an exception." Neill remarks, that nothing is so unfavourable to the productiveness of the cherry tree, as crowding of branches.

Cherries, when becoming ripe, or fully so, are particularly liable to the attacks of birds. The best remedy against these is to spread netting over the trees.

Pear trees are grown both as standards, dwarf standards (or espalier rails), and as wall fruit. We should observe, that if dwarf standards are trained in the pyramidal manner, they may stand within eight feet of one another.

Pear trees placed against a wall are usually (and preferably) trained in the horizontal manner. The fruit is produced on spurs, which spurs come from shoots more than one year old. "The summer pruning," says Neill, "of established wall or espalier trees, consists chiefly in the timely displacing or rubbing off the superfluous shoots, retaining only those which are terminal, or well placed for lateral branches. Where spurs are wanted on the older wood, about two inches of a fore right shoot are left; and if this be done early, that is, before the shoot has become ligneous, it seldom fails to form fruit buds. In horizontal training, the winter pruning is nothing more than adjusting the leading shoots, and thinning out the spurs, which should be kept close to the wall, and allowed to retain only two or, at most, three buds. In fan training, the subordinate branches must be regulated, the spurs thinned out, and the young laterals, which had been loosely nailed in during summer, must be finally established in their places. No crowding of branches should be permitted."

Apple trees are, as it is well known, grown in all possible manners. The apple tree, like the pear, bears its fruit on spurs, which proceed from branches of two or more years of age, and its culture is pretty similar to that of the pear. Quinces and medlars, if grown at all, may be managed much as apples are.

The mulberry tree is grown as a standard in the south of England, but in the north of Britain it does not ripen every year, even when placed against a wall.

The hazel, filbert, and cobnut trees are usually propagated by layers or suckers, but sometimes the two latter are grafted upon hazel stocks. The walnut is usually raised from seed, but it may be propagated by budding. All these nut trees require, or at least receive, very little pruning.

Currant trees or bushes are propagated by means of cuttings. A few trees should be placed against an east or west wall, for an early crop; and some against a north one, for a late crop. The others are usually planted as border bushes in the quarters. "They are trained as bushes from single stems of about a foot in height, care being taken to prevent the main branches from crossing each other. In winter, the young bearing wood on the sides of the branches is shortened down into spurs, from an inch to two inches in length. The leading shoots are left about six inches long." The black currant is not spurred, and it thrives best in a damp and shady situation. Gooseberries are pruned like currants, and treated in other respects like common currants.

Raspberries are propagated from suckers, planted in rows five feet apart, and each plant a yard distant in the rows. They produce their fruit on small branches, which come from the shoots of previous years, and these shoots, after maturing the fruit, die. Every winter the decayed stalks are cut away, three or four of the young canes selected for preservation, and these cut down by about a third of their height. These stalks require support, either by means of stakes, or by connecting the points of those in a row, so as to form arches, and thus support one another.

The strawberry is the only other fruit that it is necessary to notice. It derives its name from the old custom, now revived, of placing straw underneath the fruit, to prevent it being dirtied. Now, however, it is most common to employ short cut grass, obtained from the mowings of the lawns. Strawberries propagate spontaneously every summer, by suckers from the parent stem, and by numerous runners, which, sending out roots, and forming a plant at each joint, only require transplanting to form separate plants. They bear the first year of their existence, but more abundantly in the second. They may also be raised from seed. Fresh beds should be made every four or five years. They require a strong soil; and before planting them, the ground should be well manured. They are planted at various distances, but perhaps drills two feet asunder, and the plants a foot apart, are the best. They require to be well watered. In May, the runners are cut off, and this removal is repeated when the fruiting season is over. In October, the runners are again removed, and the surface between the drills stirred with a three-pronged fork. In October, also, the remaining leaves are cut away.

ASTRONOMY.

CHAPTER V.

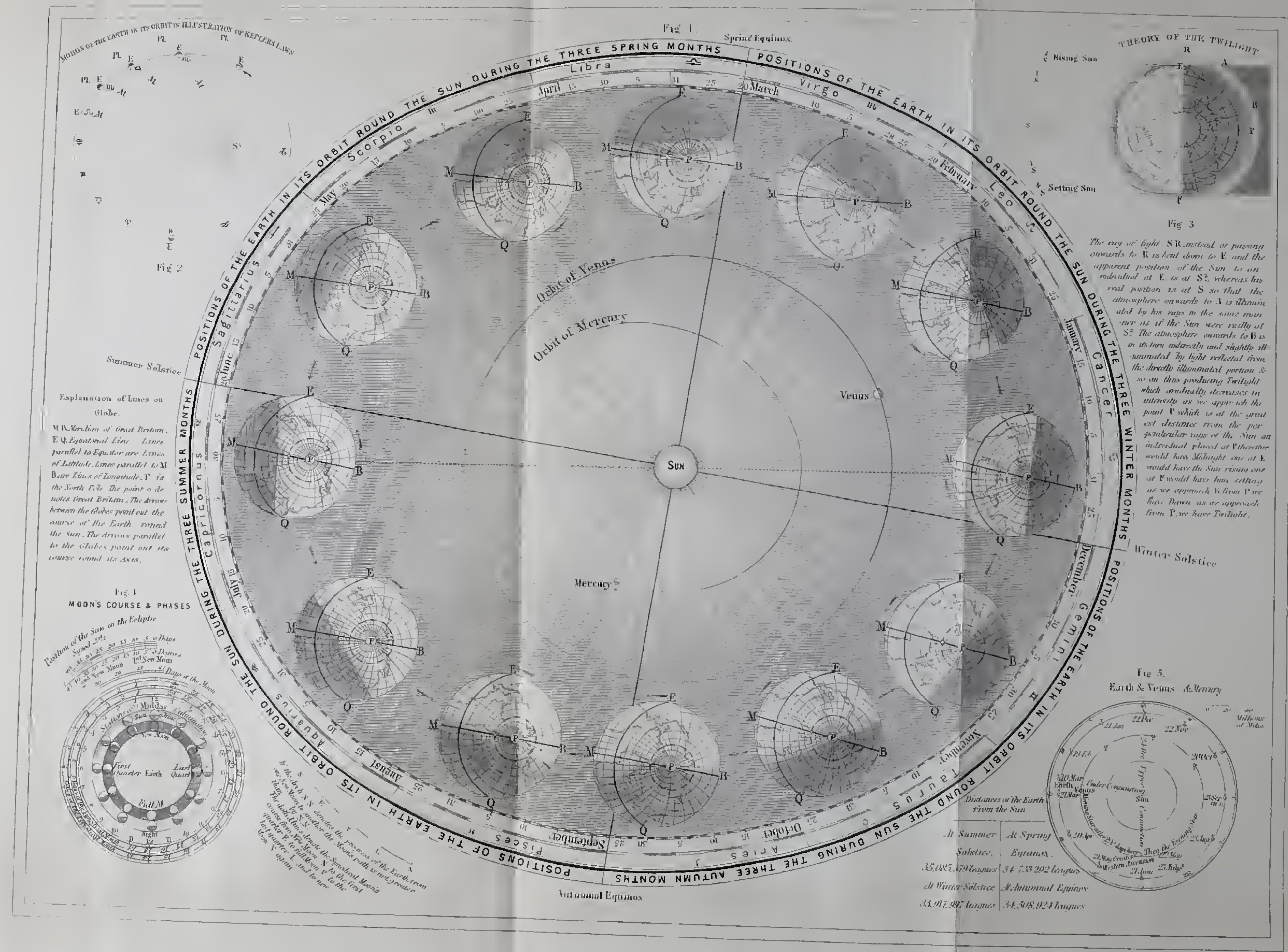
UNIVERSAL GRAVITATION APPLIED TO THE DEMONSTRATION OF KEPLER'S LAWS, AND TO THE EXPLANATION OF THE MECHANISM OF THE SOLAR SYSTEM.

A CLEAR understanding of those elementary laws of motion, which have been explained and illustrated in last chapter, is absolutely necessary to enable us to comprehend the mechanism of the solar system. A knowledge of these laws places us in a position to be able to follow a simple explanation of the different steps, by which Newton arrived at his grand demonstration of the great law of universal gravitation. It is true, that without a much more intimate acquaintance with the higher branches of mathematical science than is to be expected in the general reader, we cannot accompany that great philosopher through the abstruse problems by which he reached his splendid results; but by close attention to a few simple explanations, these results can be easily understood, and their vast importance, as constituting the basis of physical astronomy, can be fully appreciated.

At the risk, therefore, of in some degree sacrificing brevity to perspicuity, we shall recapitulate, as plainly as possible, a few of the primary truths to which we briefly drew attention in last chapter, for the purpose of recalling to the reader's mind the process by which Newton reached the first and most difficult step in his intricate investigation. If we are successful in communicating a clear idea of this great law of universal gravitation, our subsequent task, in explaining the numerous and varied phenomena of the heavenly bodies, will be comparatively easy, and will consist more in attracting attention to the beauty, harmony, and simplicity of these phenomena, than in entering into any lengthened disquisitions regarding them;—that great law being the key to the solution of every problem, and every apparent anomaly connected with the movements of the celestial orbs.

Although, as we have already seen, it was strongly conjectured by Copernicus, by Kepler, and by most succeeding astronomers down to the days of Sir Isaac Newton, that the laws of gravitation and motion, as exhibited on the earth's surface, extended to the heavenly bodies, binding, by an indissoluble tie of connection, the different members of which the solar system was composed, it was not until the time of

ANNUAL REVOLUTION OF THE EARTH ROUND THE SUN.



the English mathematician that data existed, by which these conjectures could be verified. Until Galileo detected the law of falling bodies, and demonstrated the remarkable problem involved in the composition of forces—until Descartes revealed the law of centrifugal force, and until Picard made a more accurate measurement of a degree of latitude, and henee arrived at a near approximation to the diameter of the earth, and the distance between the earth and the moon—even the master-mind of Newton was unequal to the emergency, and the proof of universal gravitation was beyond the reach of human intellect.

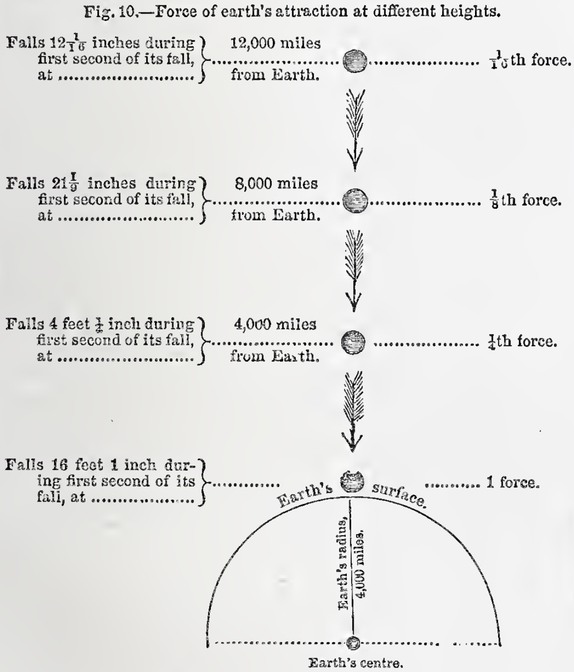
By our 5th law of motion, the force of attraction exerted by any two bodies *decreases* in proportion as the *square* of the distance between them *increases;* and by our 3rd law, the force of attraction between two bodies is *directly* in proportion to their weights, or to the quantities of matter in each.

If we could place, for example, at eertain distances from the earth, bodies so small, eomparatively, that the force of their attraetion on the earth may be left out of the ealculation, the force of the earth's attraetion upon them would be represented by the second series as follows:—

Distances of the bodies from the earth, or number of semidiameters from its centre.	1,	2,	3,	4,	5,	6,	60,	&e.
Strength of earth's attractive force at these distances.	1,	$\frac{1}{4}$,	$\frac{1}{9}$,	$\frac{1}{16}$,	$\frac{1}{25}$,	$\frac{1}{36}$,	$\frac{1}{3600}$,	&e.

The intensity or foree of the attraction of any large body is measured by the velocity which it is eapable of communicat-

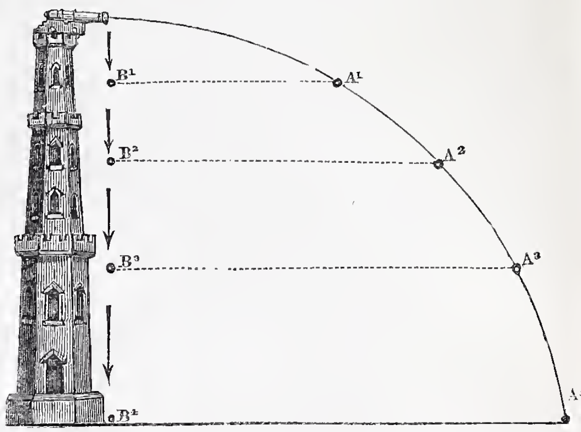
Fig. 10.—Force of earth's attraction at different heights.



ing to a small body falling near its surface. Now, experiment has proved, that at the surface of the earth—one semidiameter, or 4000 miles from its centre—the force of its attraction is capable of imparting to falling bodies a velocity of 16 feet 1 inch during the first seeond of their fall. At the distance of *two semidiameters*, or 8000 miles from its centre, this force of attraction ought, by Galileo's law of falling bodies, to be redueed to (2×2) *one-fourth* of this intensity; at the distance of *three semidiameters*, it ought to be reduced to (3×3) *one-ninth;* and at the distance of *sixty semidiameters*, it ought to be reduced to (60×60) *one-three thousand six hundredth* of this intensity, capable, at that distance, of imparting to a body during the first second of its fall, only $\frac{1}{3600}$th part of the veloeity which it imparts at the earth's surface.

We have already stated and illustrated the singular law of projectiles, by whieh it is proved, that a body falling in a curved line is as much a measure of the force of gravity at the earth's surface, as if it fell perpendicularly; that it falls from the same height in the same time, whether propelled horizontally forwards, or dropped perpendicularly downwards.

Fig. 11.—A cannon-ball shot from the top of a tower horizontally, reaches A 1, A 2, A 3, A 4, in exactly the same time in which a bullet dropped perpendicularly from same height reaches the points, B 1, B 2, B 3, B 4.



Newton asserted that the moon was an example of a body constantly falling towards the earth, but from that tendency which bodies have, by their inertia, of moving in straight lines (the centrifugal force), and the force of the earth's attraetion (the centripetal foree), being exactly balanced, the moon was therefore kept in equilibrium, which, if undisturbed by any opposing cause, would continue for ever, and retain her in her orbit, revolving round the earth in all time coming.

But it was impossible to carry a body upwards to the height of 4000, 8000, 12,000, or 240,000 miles above the earth, so as to aseertain whether or not the actual velocity which the foree of the earth's attraetion would impart to it at these distanees during the first second of its fall, would amount to one-fourth, one-ninth, one-sixteenth, or one-three thousand six hundredth part of the distanee whieh it would fall in the same time at the surface of the earth. Newton, therefore, employed the moon as the falling body, by which he eould measure the foree of the earth's attraetion at her distance from its surface.

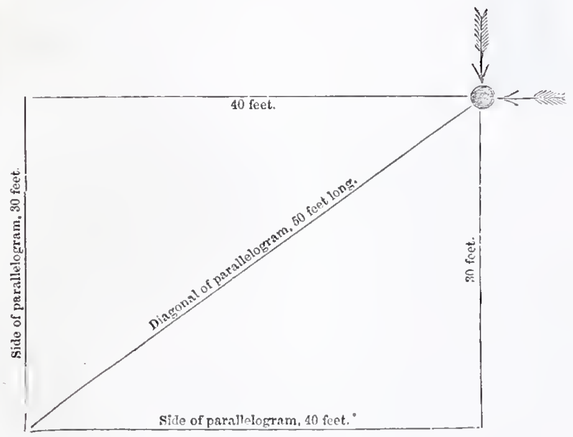
If he eould prove, then, that at the moon's distance from the earth (which is about sixty semidiameters, or 240,000 miles from its surface), a body would only fall one-three thousand six hundredth part of the distance during the first second, whieh it would fall in the same time at the earth's surface, then would Kepler's wonderful conjecture be verified and successfully demonstrated, that that mysterious power, ealled gravitation, extends its controlling influence to the planets, and that the strength of this power diminishes in proportion as the squares of the distances between these bodies increase.

But how eould Newton employ the moon as the falling body, and thus measure the distance she would fall to the earth in a second? What mighty power could he wield to arrest the moon in her onward course, and leave her to the sole influence of the earth's attraetion, and so as to become an index of its strength? Such a proceeding, had it even been possible, was quite unnecessary for Newton's calculation. He knew that if a body moves in any other than a straight line, it must be under the influenee of more than one force acting in different directions; and that, as the moon moved in a circular path round the earth, she must do so in obedienee to two forces—one, a primary impulse, sufficient to impel her forward for ever in a straight line; another, an attractive force, existing within her orbit, and exerting an

unceasing influence in drawing her away, or bending her from this straight line which she has a constant tendency to pursue. But supposing the moon to be acted upon by these two forces, how could Newton separate them, so as to discover their respective values, and find the exact velocity which would be imparted to the moon by the earth's attraction, if left to its sole and undivided sway?

It is ascertained to be one of the laws of motion, that whatever number of forces act upon a body, and whatever the directions of these forces, they can only impart one *single* motion in one *certain* direction; and their united action for a given length of time will impel a body to the same place, as if each of these forces had acted separately and successively for an equal length of time. If a body, for instance, receive an impulse which alone would propel it 30 feet in one second, and at the same instant receive another impulse which singly would propel it in a different direction 40 feet in one second, it would move, under the united influence of these two forces, along the diagonal of a parallelogram, the direction of whose sides will be the direction of the two forces, and their lengths 30 and 40 feet, and the body will pass over 50 feet in the first second of time.

Fig. 12.—Parallelogram of forces.



By this law, therefore, if we know the strength and direction of the two forces respectively, we can calculate the direction and the distance which a body will be propelled in a given time; and, *vice versa*, if we know the distance and direction in which a body is propelled in a given time by two or more forces, we can calculate the strength and direction of these forces respectively.

Both the law of projectiles, therefore, and the law of the composition and resolution of forces, came to the aid of Sir Isaac Newton in his calculation of the strength of the earth's attraction upon the moon. By the observations of Flamstead, he knew the exact distance which the moon travelled in her orbit in a given time; and by the calculations of Picard, he knew the exact distance of the moon from the earth; he could therefore construct a geometrical figure (see fig. 9 in last chapter), and from the principles above laid down, he could calculate the exact distance which the strength of the earth's attraction would cause the moon to fall towards it in one second of time, at the distance of 240,000 miles from its surface.

The distance which rigid mathematical demonstration proved that a body at the distance of the moon would be drawn towards the earth by the strength of its attraction, corresponded exactly to the observed phenomena, and to the influence which gravitation exerts upon bodies on and near the earth's surface, diminishing in force in proportion as the square of the distance increases.

Again, we have already shown, that a body projected horizontally from the top of one of the highest mountains on the globe, would, if propelled with sufficient force, circulate round the earth for ever, like the moon. The force, however, which would enable a body to perform one revolution round the earth, so as to overcome the great power of the attraction of gravitation so near its surface, must be enormous; and so rapidly must it perform this revolution, that, according to mathematical calculation, it must revolve round the earth, in 1 hour, 23 minutes, and 22 seconds, so as to overcome the force of gravity and remain in equilibrium. At the distance of the moon, if the force of attraction were as powerful as at the earth's surface, a body must circulate round the earth in an orbit like that of the moon in 10 hours, 45 minutes, 30 seconds, so as to make the centrifugal force counteract the force of gravity. But the moon takes 27 days, 7 hours, 43 minutes to perform one revolution round the earth; instead, therefore, of gravity being of the same force at the moon as at the earth's surface, it must be nearly 3600 times less powerful. Here, then, is another proof that the force of attraction diminishes in proportion as the square of the distance from the attracting body increases.

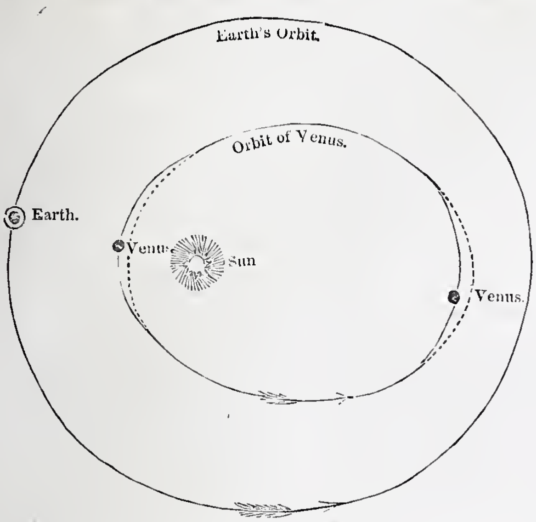
Having fully satisfied himself that the attractive power of the earth extended to the moon—that it was the invisible and indissoluble tie which connected these two bodies together—and from the earth being so much superior in mass, or weight, to the moon, that it was the cause of the latter revolving around the former, instead of their revolving around each other, which they would have done if their masses had been more nearly equal—Newton extended the application of his discovery to the other members of the solar system. He saw all the planetary bodies revolving round the sun as a common centre, and he asked himself the question, are all these bodies bound to the sun, and are their revolutions caused by his attractive influence, in the same manner as the moon is retained in her orbit by the attraction of the earth? If all these planets are deflected from tangents to their orbits, or, in other words, are bent by the sun's influence from straight lines touching their orbits, to such distances in a given time, say one minute, as they ought to fall towards the sun were they solely under the influence of his attractive force—supposing that attractive force to diminish as the square of the distance increases—then the forces which deflect them towards the sun are not merely *similar* to, but *identical* with, terrestrial gravity,—binding the whole into one harmonious system,—and then is the universality of the great law of gravitation incontestably demonstrated.

Newton found, by calculation, that such was actually the case, and hence he deduced the following general law:—"Every particle of matter in the universe attracts every other particle with a force *directly* proportioned to the mass of the attracting particle, and *inversely* to the square of the distance between them." Not only do large masses of matter, such as the earth, attract other smaller masses of matter, such as bodies near its surface, or the moon at a distance, but every particle of matter, both in the earth and in the moon, attracts every other particle in obedience to this universal law, as is proved by the following examples. The force of the earth's attraction is diminished as we ascend high mountains, consequently matter becomes lighter, and a pendulum which strikes seconds must be shortened as we ascend; but it was also proved, by the experiments of Messrs. Airy and Whewell, that matter becomes lighter from the diminution of gravity as we descend into the bowels of the earth; they found it necessary to shorten their seconds pendulum at the bottom of the Dalcoath mine, from the circumstance that the stratum of the earth *above*, opposed, and in a certain proportion counteracted, the attractive power of that below. Bouguer and La Condamine found that the lead was deflected from the plumb-line at the foot of the Andes, by the attraction of that great mountain mass. Leaden balls delicately suspended from the roof of an air-tight room, have also been observed to be attracted in some degree towards each other.

Not only, then, does the sun attract the planets, and the planets attract their moons or satellites, but all these bodies

attract each other *directly* in proportion to their masses or weights, and *inversely* to the squares of the distances between them. The sun, for instanee, attracts the planet Venus, which circulates round him within the orbit of our earth; but the motions and orbit of Venus are not left to be determined by the attractive power of the sun alone, but are in some degree influenced by the attractive power of the other planets in the system. When Venus is in that part of her orbit which lies between the sun and the earth, the earth draws her away from the sun; and when she is in the opposite part of her orbit, the attraction of the earth is acting in the same direction as that of the sun, and contributes, although but slightly, from the increased distance, to draw her nearer the sun.

Fig. 13.—Modification of orbit of Venus by the attraction of Earth.



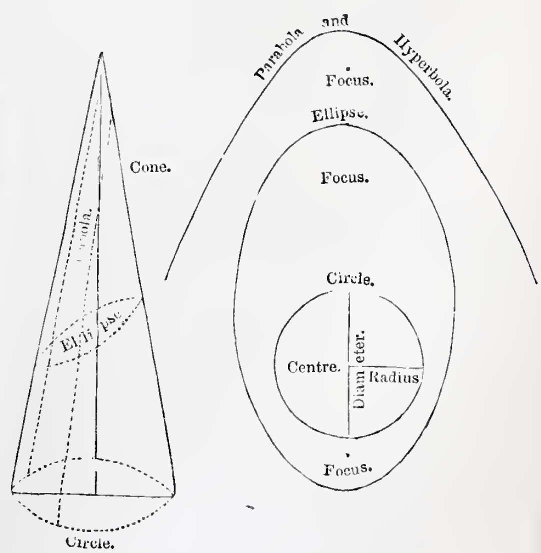
Again, not only does the sun attract all the planets, but the planets also attract the sun; the whole of the planets put together, however, are only about one-thousandth part of the substance of our grand central luminary, and they are, moreover, at enormous distances from his surface, and are acting in different directions; hence the reason why his position is so little influenced by their attraction. But is it legitimate to apply the law of attraction, which Newton proved to exist between particles of matter, to large bodies like the planets, and is it correct to look upon them as if they were mere *particles?* By a very difficult and intricate mathematical process, he proved that if a planetary body is a perfect sphere, so that its centre of gravity is in the centre of its mass, then its attractive influence is exactly the same as if it consisted only of one particle of matter situated at its centre. But with regard to those bodies which are not spheres, such as the earth, which is bulged out at the equator, and flattened at the poles, a slight error would arise from considering it a particle of matter; this peculiar formation gives rise to phenomena in the motions of bodies near each other, which can only be understood by taking that circumstance into ccount.

Having proved to his satisfaction that the attraction of gravitation is an inherent property of all matter, that it is the invisible chain which connects the planets in the solar system to the sun, and which binds the moons or satellites to their primary planets, and that it is the power by which the different particles of which each planet is composed are bound in one solid mass, Newton set himself to determine the reason why, in accordance with Kepler's *law*, the planets revolved in elliptic orbits round the sun. Might they not, or ought they not, rather to revolve in circular orbits? Is there anything in the law of universal gravitation to explain the apparently capricious course which is pursued by each individual planet? To settle this question, he called his profound knowledge of mathematical science to his aid, to enable him "to determine the nature of the curve which a body would describe in its revolution about a fixed centre, to which it was attracted by a force proportional to the mass of the attracting body, and decreasing with the distance, according to the law of gravitation." This investigation soon led him to the remarkable discovery, that a spherical body, gravitating round a centre regarded as fixed, may describe any of those curves to which geometers give the name of *conic sections.* He was surprised to find that it would depend solely upon the velocity, distance, and direction of the gravitating body, when it commences to circulate in its orbit, whether that orbit will be an *ellipse*, a *circle*, a *parabola*, or an *hyperbola.* The curve which the body *must* describe will be limited to one or other of these figures, of a greater or less degree of eccentricity; and in every case the fixed point about which the body revolves, *must*, of necessity, be the focus of the conic section described.

Every one is familiar with the appearance of a cone—a figure to which a sugar-loaf bears a marked resemblance. The base of a cone is a circle, and every section parallel to its base is a *circle.* The satellites of Jupiter revolve in circles. Cut the cone oblique to its axis, and the line of section will be an *ellipse*, which represents the orbits of the planets. Cut it again parallel to the slope of the cone, and the line of section will be a *parabola;* cut it parallel to the axis, and the line of section will be an *hyperbola;* both of which figures represent the anomalous orbits of those extraordinary bodies called *comets.*

Newton also demonstrated, by a simple geometrical problem, that Kepler's *second* law must of necessity be true—that the *radius vector*, or the line joining the centre of the sun and any planet, sweeps over equal areas in equal times; that is, suppose the whole area included within the earth's orbit to be divided into twelve triangles of equal areas, having arcs of this orbit for their bases, and lines connecting the earth and the sun at the commencement of every month for their sides, it follows that no three of these arcs can be equal, from the earth's orbit being an ellipse; but Kepler discovered, and Newton mathematically proved, that, however different the length of these arcs which were passed over in equal times by the earth, the areas of the triangles which they subtended, with the centre of the sun at their apex, were all equal.

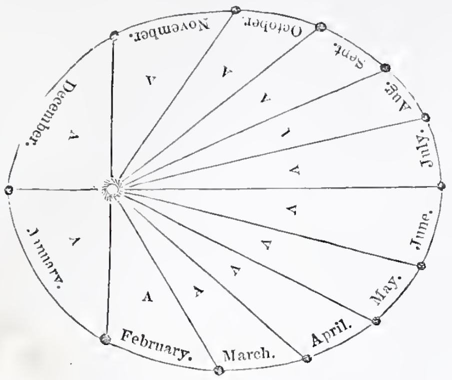
Fig. 14.—Conic Sections.



The same investigation led Newton to the proof, that the velocity in which a planet moves in its orbit round the sun, is inversely proportional to the square of its distance from

that orb; consequently, as the planets move in elliptic orbits round the sun—the sun occupying the common focus of these orbits—a planet must move with very different velocities at different times; the nearer a planet approaches the sun in its orbit, the greater its velocity; and the farther removed, the slower it becomes. Since a planet, then, must be at a much greater distance from the sun in one part of its elliptic orbit than in another part, what is the reason that it does not either fly off into space, and so get beyond the controlling influence of the sun when moving in that part of

Fig. 15, illustrating Kepler's Second Law.



A, Areas of equal triangles.

its orbit which is farthest away from him, or, when in the part of its orbit nearest the sun, why does it not fall into that orb? Because, at whatever distance a planet is removed from the sun in its orbit, and at whatever velocity it is moving, the centripetal and centrifugal forces are always equal—as the one increases the other increases, and as the one diminishes the other diminishes. Although it might be supposed, then, that there is some danger of a planet falling into the sun when in the part of its orbit nearest him, on account of the power of his attraction (centripetal force) *not* increasing in proportion to the diminished distance between them, but in proportion to the *square* of this distance, still we must remember, that the velocity, and therefore the centrifugal force, is increased in the same proportion. The same cause prevents a planet darting off into space when at its *aphelion*, or farthest distance from the the sun; here the power of the sun's attraction (centripetal force) is diminished in the above proportion, so that, if the planet is double the distance from the sun which it was at its *perihelion*, the attraction is diminished to one-fourth.

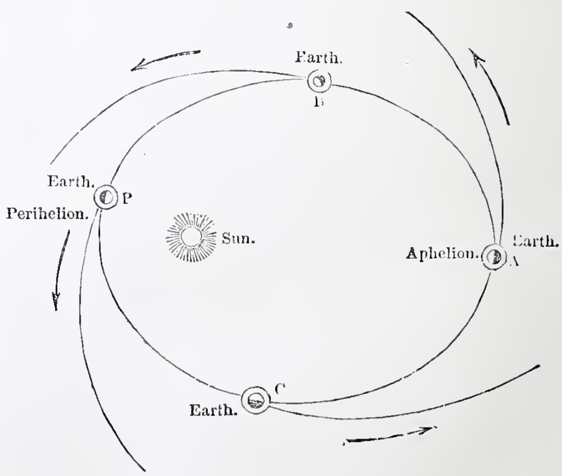
In the following rude diagram, showing the earth's elliptic orbit round the sun, the arrows point out the directions in which the centrifugal force constantly tends to impel the earth, and which, were it not that this force is exactly balanced by the sun's attraction in all parts of its orbit, it would succeed in propelling it, and so remove it, from the sun's influence.

Suppose the earth to commence moving round the sun at its *aphelion*, or farthest distance from the sun, at a certain velocity, the sun's attraction bends it into a curve in the direction of B; as it approaches and passes this point, and till it nearly reaches P, its velocity is constantly increasing, from the circumstance that the sun's attraction is acting in such a direction as to accelerate the primary velocity; by the time the earth has reached the point P—its perihelion—its velocity is increased to the utmost, and it has acquired its greatest centrifugal force. During the whole course of the earth, however, through this half of its orbit, from the point A, through B to P, the distance between it and the sun has been constantly diminishing, and the power of his attraction increasing in the same ratio with the increased velocity of the earth; so that, at the point P, where it has acquired its greatest velocity and its greatest centrifugal force, it has also reached the nearest point in its orbit to the sun, where the power of his attraction is strongest, and therefore sufficient to retain the earth in its orbit, and to bend its course towards C. As the earth approaches to C, and passes through that point to A, the distance between it and the sun is constantly increasing, and the influence of the sun's attraction diminishing, in the ratio above-mentioned; so that, by the time it has reached A—its aphelion—the sun's power to retain it in its orbit is weakest, and if the velocity and centrifugal force had continued as powerful as at the point P, our globe would have darted off—at first in a curve, but afterwards in a straight line—into space in the direction of the arrow: but during its whole course in this half of its orbit from P to A, the sun's attraction has been acting in opposition to the earth's motion, and consequently retarding its velocity; so that, although at the point A, the sun's attraction has the least power over the earth from the distance between them being greatest, yet the earth's motion has become so slow, and the centrifugal force so weak, that it is amply sufficient to retain the earth in its orbit, and make it revolve around him for ever.

That the velocity of a body revolving round a centre increases and diminishes as the square of the distance between them increases or diminishes, may be illustrated by a very simple experiment:—Attach a small leaden bullet to a strong but thin cord, of, say, eight feet long; make it revolve in a vertical direction, and note the time it takes to perform so many revolutions, at the slowest rate possible, so as to keep the cord at the stretch. Make it revolve with half the length of the cord, and it must perform, not *double* the number of revolutions, but *four* times the number, in the same time, so as to keep the cord at the stretch. Take one-third the length of the cord, and it must perform *nine* times the number of revolutions in the same time, and so on. Again, if the velocity of the ball be doubled, it will require a cord *four times* stronger; if trebled, *nine* times stronger, and so on; showing that the centripetal and centrifugal forces increase and diminish in the same ratio.

Kepler's *third* law, as has been already stated, is, that "the squares of the times occupied by any two planets in revolving round their orbits, are to one another as the cubes of their mean distances from the sun." "Of all the laws," says Sir John Herschel, "to which induction from pure

Fig. 16.—Earth's Orbit round the Sun.



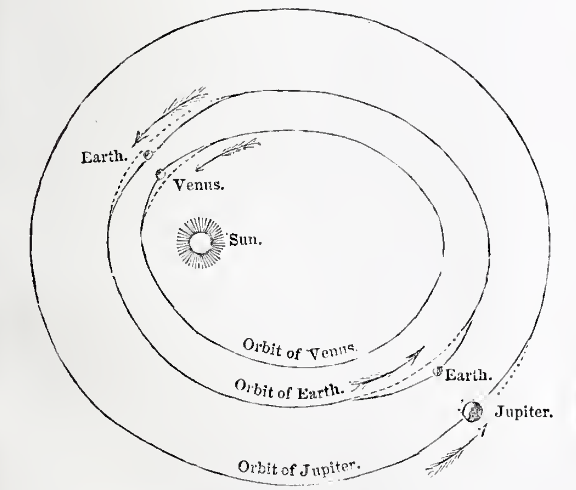
observation has ever conducted man, this *third law* (as it is called) *of Kepler* may justly be regarded as the most remarkable, and the most pregnant with important consequences." From it, Newton proved that the distances in which any two planets were bent or deflected, in equal times, from tangents to their orbits, were connected in the same manner, and bore the same proportion to one another,

as the *deflections* of the same planet in different parts of its orbit in equal times; that the amount of the *deflections* in both cases were inversely proportional to the squares of the distances from the sun's centre. As all the planets, therefore, large and small, light and heavy, are deflected from straight lines touching their orbits, inversely as the squares of their distances from the sun, it follows that they would be all deflected *equally* if at the same distance from him, and would fall towards him with the same velocities, if their centrifugal force were suddenly arrested, leaving them entirely abandoned to the sun's attraction. And were any planet taken from its orbit, and launched anew into space, at the place, in the direction, and with the velocity, of any other planet, it would describe the very same orbit, and in the very same period, which that other planet describes.

The observed motions of the moons or satellites of the great planets, show that the latter exert a force of the same kind upon the former, as the sun exerts over all the planets. In short, all bodies in the universe attract, or pull, each other with forces exactly proportioned to the masses of the bodies pulling—the largest body, in every case, attracts, or pulls, with the greatest force at an equal distance. Suppose the earth to attract a body at a certain distance with a certain force, Jupiter would attract it with 340 times, Saturn with 101 times, and the sun with 354,936 times a greater force, from the circumstance that the *masses*, or *densities*, although not the *sizes*, of these bodies are this number of times greater than the density of the earth.

Having now shown that every particle, and every mass of matter, is endowed with the inherent property of attraction; having proved that every planet and every satellite is not only under the influence of the sun's attraction, and that of its primary, but more or less under the attractive influence of all the other planets, in proportion to their distances and densities; and having stated the law which this attractive force in all cases obeys, we will conclude this chapter by a short application of this great law of universal gravitation to the bodies composing the solar system, explanatory of their complicated motions.

Fig. 17, showing the mutual attractions of the Planets.



Were the solar system composed of only two bodies—the sun and a solitary planet revolving around him—and did we know the distance of this planet from the sun, the intensity and direction of the impulse which originally set it in motion, and the density of both the sun and the planet, nothing could be more easy than to give the exact size and form of its orbit, its period of revolution, and, in short, its history in all time past, and for all time coming. But the moment we add another planet, we render the calculation more complex; we must have the same knowledge regarding the distance, density, and the direction and force of the primitive impulse of this new planet which we had of the first, and then we must take into account the amount of attractive influence which it can exert upon the first planet in every different part of its orbit, thus disturbing and altering its motions. If, besides adding another planet to the system, we also add a moon to the first planet, we render the calculation infinitely more difficult—the moon's influence upon the motions of the planet (which will be greater or less, according to her mass, and to the form of the planet about which she revolves) must now also be taken into account in the solution of the problem; and as we go on adding planet after planet, we continue to render the subject so much the more complex.

In reality, then, the orbit of a planet is not determined by the influence of merely two forces—the sun's attraction, and its centrifugal force, which was communicated by the primary impulse—but, in addition to these two forces, we have to take into account the conjoined influence of the attractive powers of all the other planets in the system, ever varying, from the constant variation of their different positions, but ever acting inversely in proportion to the squares of their distances, and directly in proportion to their masses. The earth, for example, as shown in the following figure, would revolve in an orbit represented by the dotted line in the direction of the arrows, but being influenced by the attraction of the planet Jupiter, follows the path represented by the black line; while, in another part of her orbit, she is drawn in a different direction, away from her natural orbit, by the influence of the planet Venus.

The mass, or density, of the sun, and of every individual planet, being known, as well as the intensity and direction of the primitive impulse, and the mutual influence which all these bodies exert upon each other at every different point of their orbits, being calculated, the astronomer is enabled to give the history of the solar system for coming ages; nay, so nicely balanced are the retarding, accelerating, and counteracting forces among all the bodies composing the solar system, compelling them to pursue their paths with undeviating accuracy, and so well are these paths known, that modern science has accomplished the wonderful feat of pointing out the spot where a new planet must exist, from the observed influence of some disturbing force acting on the orbits of those already known—and in that very spot a new planet has been found!

FARADAY'S SPECULATION ON MATTER AND ELECTRIC CONDUCTION EXAMINED.

By Δε. Θ.

ARTICLE I.

1. There is matter of much importance in the speculation promulgated by Dr. Faraday, respecting the laws of electric conduction, and the nature of matter, (see p. 258.) There is much in the able views of the writer that must attract the respectful attention of the scientific world; for, unquestionably, however we may feel indisposed to recognize the entire correctness of the opinions set forth in his essay, we cannot but perceive in them the germs of that magnificent generalization of nature's most secret workings, as well as of the rules by which those workings are regulated, which have so long eluded the anxious grasp of the most aspiring philosophers.

2. The few examples adduced in that essay, of the absurdity of the ordinary atomic theory, will do more to rouse philosophic minds from the pressure of early prejudice, than volumes of perplexing arguments, founded upon new-fangled hypotheses.

3. In connection with this subject, I would draw the attention of your readers to the observations on the subject of electric conduction in my treatise on voltaic electricity, published in this work; for I believe it will be found that the truth of many of those observations is fully borne out by the

facts detailed in Professor Faraday's letter. For instance, take the following remarks upon Faraday's views respecting the mode by which inductive influence is assumed to be propagated:—"Unfortunately, on applying the foregoing views (Faraday's) to the explanation of induction in every case, difficulties occur, which it appears to us almost impossible to surmount. For example, if we are to suppose all arrangements of what Dr. Faraday calls 'contiguous particles' of ponderable matter to be similar in all respects to the arrangement of the silken threads in the liquid dielectric—that is, pole to pole, in a continuous chain—this molecular theory of induction might be conceived to hold good. But Dr. Faraday himself admits the existence of greater or less *intervals* between the particles of the interposed dielectric; and in the case of a vacuum, he recognizes the fact of induction occurring as well in empty as in full space, and intimates 'that nothing in his theory forbids that a charged particle in the centre of a vacuum should act on the particle next to it, though that should be half an inch off.' Now, surely, if inductive influence can operate from particle to particle, or from ball to ball, at the distance of half an inch *in vacuo*, there is nothing to prevent the same influence operating at the distance of half an inch *in pleno;* and in either, if the inductive influence can take a flying leap of half an inch from one particle to another, why should it not pass over the same distance from a charged to an uncharged ball, without the aid of intervening particles? It strikes us that, if, as has been proved in the case of a vacuum, a charged body is capable of influencing an uncharged one, without the intervention of contiguous particles, there can be no possible reason why induction should depend upon an action of contiguous particles in one case, and not in the other. If we are to assume any medium to be necessary for the propagation of an influence, why not recognize the existence of a universal ethereal principle undiscoverable by our limited powers of perception, but nevertheless omnipresent, and independent of matter? Such a medium might well be supposed adequate to propagate inductive as well as other influences, and would satisfactorily explain various disputed and unintelligible points in the modern theories of induction." (P. 258.)

4. From the above extract it will be seen that, although Dr. Faraday did not *then* perceive the necessity of a universal continuity of matter, that necessity was impressed upon my mind; the only difference being, that the universal ethereal principle which I conceived to exist, was independent of matter, in our *general* acceptation of that term—although, nevertheless, *matter*, when applied to a *something* having an existence; but one too refined to be appreciable by *our* limited powers of perception; whereas, Dr. Faraday's present views recognize a continuity arising from certain centres of power, represented by two atoms, which will mutually penetrate to the very centres, thus forming one atom or molecule, with powers disposed either uniformly around it, or arranged as the resultant of the powers of the two constituent atoms. Now, whether we are to recognize this modification of Boscovich's assumption of atoms, consisting merely of centres of force, or the assumption of *a universal ethereal principle, or a homogeneous non-atomic ethereal fluid*, into which matter in its *simplest condition* may be resolved—infinite space being supposed capable of being occupied by such matter, which, *in such state*, is capable of being intersected in any direction—one thing is quite clear, that there must be a continuity of some sort or another in all material arrangements. Such an assumption will at once enable us to conceive the existence of a continuous principle, in what would in common language be termed a *perfect vacuum;* and the difficulty of electrical communication between two separated bodies *in vacuo*, or of induction between the same bodies, will be easily obviated.

5. With respect, however, to the instances adduced by Dr. Faraday, wherein he shows that metals containing, *in a given bulk*, the *least* number of atoms, are *better* conductors of electricity than certain other metals, which in a *like bulk* contain a *greater* number; it strikes me that the influence and operation of the specific heat of each metal, and also the specific or natural electrical condition of each metal, should be taken into account in estimating their respective conducting powers; for we may perceive that in those metals generally, whose conducting power is *greatest*, the negative condition is *highest*, and we may conceive that in those metals which, *in a given bulk*, contain the *greater* number of atoms, the inherent quantity of heat being restricted to a *smaller* space, by the existence of that *greater* number of atoms, will be in a *more compressed* state, and, in consequence, may establish a certain condition of the metal *unsuited* to the *facile* passage of the current; whereas, where but *one* atom existed *in a given bulk*, the specific heat of the metal would have *more* space, and therefore, as in the case of gold or silver, offer *less* obstruction.

6. Nature's operations are so intimately connected with all the phenomena of voltaic electricity, and through it with chemical changes generally, that the consideration of Faraday's views becomes a fitting subject for inquiry, particularly when we feel that men's minds are too apt to run from one extreme into another, and thus to produce darkness where there should be light, and perpetuate error while on the very threshold of truth.

7. In the present instance, our apprehensions are not without good grounds; for, singular to say, it would appear that the very philosopher who has done so much service to science, by drawing public attention to this subject, has unwittingly fallen into the opposite extreme, or rather, has brought to bear upon certain phenomena of matter, metaphysical views which, however ingenious or correct in the abstract, can only have the effect of mystifying the minds of all but the most able, and which, we must confess, we do not conceive to be requisite for the satisfactory explanation of those contradictory effects which Dr. Faraday finds it so difficult to reconcile according to existing theories. In endeavouring, therefore, to restrain the mind as much as possible to the consideration of *facts*—so long as as there appear facts, or well-supported presumptions of facts, adequate to the satisfactory explanation of natural phenomena—we are only pursuing the course suggested by Professor Faraday himself, when he says, "I cannot doubt but that he who, as a mere philosopher, has most power of penetrating the secrets of nature, and grasping, by hypothesis, at her mode of working, will also be most careful, for his own safe progress and that of others, to distinguish that knowledge which consists of assumption—by which I mean theory and hypothesis—from that which is the knowledge of facts and laws; never raising the former to the dignity or authority of the latter, nor confusing the latter more than is inevitable with the former."

8. Applying, therefore, this wholesome caution to the consideration of the facts connected with the affections and properties of matter, let us inquire whether these facts are adequate to the explanation of the cause of electrical conduction and insulation; and whether we can, by any application of such facts, reconcile those discrepancies which have suggested to Faraday and others the necessity of a remodelling of our present opinions. Our opinions, then, are simply these, that no hypothesis of "centres of force" is necessary for the explanation of conduction and insulation in metals or other substances not separated by sensible distances; but that, for the explanation of *induction*, whether electric or magnetic, and electric *conduction* or communication between bodies separated by *sensible* distances, in *vacuo* or in *pleno*, we are only called upon to assume the existence of the universal non-atomic ethereal fluid, occupying infinite space; and thus establishing, without the aid of metaphysical subtleties, the principle of continuity throughout the whole material creation;—in other words, what we *do* know, we consider adequate to the explanation of electric conduction and insulation where there are *no* perceptible intervals between the conducting substances; but with respect to *conduction* and *induction* between bodies separated by sensible distances, what we *do* know we do *not* consider adequate—but, as in this case we are compelled to assume, we assume as little as possible; that little being much less than Faraday's, or rather Boscovich's hypothesis—but equally adequate, and not involving the metaphysical conceptions of centres of force, or immaterial points operating as matter, *without being material*, and producing all sorts of substance by unions of nothing! Our assumption merely recognizes an ethereal fluid, sufficiently *subtile* to penetrate the smallest in-

terstices of the proper forms of matter, and sufficiently *material* te pessess some, at least, ef those properties and powers which we are in the habit of eonnecting with our conceptiens of matter. With respect to our first opinion, let us throw aside for the moment the idea ef that atomic arrangement in bodies which would cause the atoms or particles to be separated at every point, and the intervals between them to be unoccupied by anything substantial—in fact, te be absolute voids; for such an arrangement is mere assumption, unsupported by anything like probability, and there is not a shadew of a reason for the supposition of empty space between the component particles of bodies. Let us merely censider what we know te be *facts*, if we know anything—namely, that bodies are made up of particles se inconceivably minute as te pass eur power of recognition; but whether these particles are a *congeries* of what are called *atoms*, er whether they are atoms themselves, we cannot prove, and, therefore, will not discuss in this place; let it suffice us to knew, that these particles are so centiguous te one another in a body, that we cannot discover any interval between them. We know, however, that there *are* intervals from the centraction and expansion of bodies, and we also know that electricity may be conducted from one body to anether by a substance—say a metal—whose constituent particles or atoms are thus separated by insensible intervals, and therefore that the conductien is frem ene particle te another, *across space;* and we further know, that of two bodies—say metals—both of which are made up of particles so *separated*, one body conducts electricity freely, the other with difficulty, or *not at all*; in which case the latter is called an insulator, while the fermer is a conductor. Seeing, then, that in two bodies similarly constituted of particles so separated, there exists so great a differenee in cenducting pewer, Faraday draws his conclusion ef the inadequacy of the atomic theory, because, as he says, "space cannot be a conducter in one case, and an insulator in another." But here we conceive he is in fault; not in this assertion regarding space, but in the eonelusion he draws, that the idea ef *space* must be discarded altogether, and that a new view of the nature of matter must be adopted in order to get ever the apparent absurdity. Now we contend, that a new view is not requisite, fer that the absurdity enly exists upon an assumption springing from the *Daltonian* theery of atoms—viz., that conduction is somehow dependent upon space—whereas Faraday's own researches have demonstrated that *space* has nothing whatever to do with it; for he has shown that empty space, or the nearest approach we can make te it, in the best possible vacuum, does *not* prevent the passage ef electricity between conducting substanees *half an inch apart*. How then are we to suppose that space *prevents* the passage ef the current between conducting *particles* separated by an inappreciable interval, or that it is an insulator? Is it not clear, therefore, that space, if empty, taken by itself, has *nothing whatever to do with conduction or insulation;* and that, if enc body be a *good* conductor or a *bad* conductor, and another bedy a goed *insulator* er a *bad* insulator—the cause thereof is *not* to be referred te the existence of space between particles, but rather te the mode of aggregation and arrangement of the particles themselves—the simple or compound nature ef these particles; that is, whether they be particles of true elementary substance, er ef a substance composed of twe or more particles combined; and, finally, the density, specific heat, and specific electrieal conditien of the substances compared? We de not assign, as an additional cause of difference, that which, in our opinion, *fills the space*, because we do not see any difficulty in explaining conduction and insulation without it. The above inferences will, we coneeive, appear te flow naturally from the relations between, and the affectiens and comparative preperties ef, the various elementary substances, after careful consideration ef the annexed table :—

Metals.	Specific gravity.	Assumed number of atoms in a given bulk.	Equivalents or atomic weights.	Electrical conducting power, and heat evolved by current.	Resistance to passage of current.	Specific heat.	Specific electrical condition, zinc being unity.	Pouillet's calculation of electrical conducting powers.	Despretz's calculation of conducting power for heat.
Silver, . . .	10·47	1·00	108·3	6	1	·057	10, — —	5152	97.3
Copper, . . .	8·900	2·87	31·71	6	1	·095	9 —	3838	89.82
Gold, . . .	19·25	1·00	199·21	9	1½	·032	10, 9, — —	3975	100·
Zinc, ...	6·900 to 7·191	2·27	32·31	18	3	·095	1 + +	?	36·37
Platinum, . .	21.47	2·20	98·84	30	5	·032	9 — —	855	38·1
Iron, ...	7·248 to 7·788	2·90	27·18	30	5	·114	5 + —	600	37·41
Tin, ...	7·291	1·30	58·92	36	6	·056	3 +	?	30·38
Lead, . . .	11·35	1·12	103·73	72	12	·031	3, 4, +	?	17·96
Palladium, . .	11·80	2·	53·36			·0555	11 — — —	5791	?
Mercury, . .	13·58 solid 15.61		202·86			·03	9, 8, —	100	?

6. In the above table it will be observed that there is a striking relation between the conducting powers of metals for electricity, their conducting pewers for heat, and their specific or natural electrical condition,—those metals which are least positive in the scale being the best electrical conductors; and those which are most positive, the worst. It will also be seen that where the specific electrical cendition is lowest or least positive, the quantity of heat developed during the passage of the current is also lowest, with a single exception—that of platinum; and that the resistance to the passage of the current is in proportion to the quantity of heat developed. We shall also find that those metals, *including* platinum, which are bad conductors of heat are alse bad conductors of electricity, and the centrary Furthermore, it will be observed, that the product of the specific heat by the weight of the equivalents of mest of the metals is a constant quantity, and that it is so in *all* of them, if the equivalents of silver, gold, and mercury be reduced to one-half, which for various good reasons it is believed they should. For instance, if we examine silver, the specific gravity of which is less than half that of platinum, we shall find, that after palladium, it stands highest, according to Pouillet and Harris, in electrical conducting power; that the heat evolved in the passage of the current is equally

low with that evolved by copper, and *lower* than any of the other metals, and that the resistance is consequently less. We shall also perceive that its conducting power for heat is highest of any, excepting gold, which it very nearly equals; and further, that if the atomic weight, 108·3, be halved, which, in the opinion of some of the ablest living philosophers, it should be, the equivalent thus halved and multiplied by the specific heat, will give a product which will agree with that of the other metals in the table—assuming the equivalents of gold and mercury to be also halved—and therefore that the product of specific heat by chemical equivalent may be taken as a constant quantity. We may here observe, that, according to Faraday's table, the conducting power of silver is inferior to that of gold and copper; silver being only 4·66, while gold is equal to 6, and copper to 6·33; but in Harris's tables, the resistance of gold is declared to be one-half more than that of silver and copper; and the results of Pouillet's very accurate researches show, that silver should number highest in the scale except palladium, the latter being calculated at 5791, silver being 5152, and gold only 3795. We are justified therefore in accepting Pouillet's calculations as the most correct, seeing that his results are supported by those of Harris, obtained by quite a different method. But this is not all; for it appears clear, that the reduction by one half of the equivalents of silver, mercury, and gold, completely upsets the argument of Faraday, against the sufficiency of the atomic theory, on the ground of the metal which contains the fewest atoms being the best conductor; for if equivalents of the metals he has contrasted, be thus reduced, the number of atoms therein in a given bulk will be doubled, so that silver and gold, which in Faraday's table appear to contain in a given bulk but one atom, really contain two; that part of his argument therefore, founded upon *such* assumptions, cannot hold good, no matter how cogent may be his reasons upon *other grounds* for rejecting the *Daltonian* views of the atomic construction of matter. Again, take the case of gold, another good conductor of electricity, we find it to be also a first-rate conductor of heat, possessing high specific gravity, developing a greater quantity of heat than silver in the passage of the current, and therefore offering an increased proportional degree of resistance; but its density is nearly double that of silver; we must therefore suppose that less space exists between its constituent particles, but it does not appear that its conducting powers are *improved* by the consequent greater contiguity of its particles, or the diminution of its space; on the contrary, that less dense metal—silver, whose particles we must conclude to be farther apart, appears to be the better conductor. Let us now observe platinum: here the conducting power for electricity is only one-fifth of that of copper or of silver, according to Pouillet and Harris; it is an equally *bad* conductor of heat according to Despretz. The heat evolved in the passage of the current amounts to five times that of silver, and there is consequently five times the resistance; its density is still greater than that of gold, we may therefore suppose its particles to possess a much closer aggregation; but in this case likewise, the diminution of the insensible spaces or intervals does not produce an increase of conducting power, for the difficulty of conduction is considerably augmented; it is also to be observed, that the connection between a highly negative condition and facility of conduction, does not in this instance appear to hold good. In this respect alone, platinum appears to be an exception to the general rule; but it would seem to possess a property not possessed in their *natural* state by the other highly negative metals in the scale, which would almost justify our classing it with those positive metals which are *bad* conductors, and in which there appears to be a relation between their *plus* condition and electrical conducting powers; namely, that extraordinary property it is known to possess, of attracting gaseous and even fluid bodies more negative than itself to its surface, and even within its pores, but without actual combination, and *promoting* their combination with other sorts of matter. It is questionable whether this metal is so highly negative as is generally supposed; it may therefore on closer inquiry prove to be *no exception*, and its *not* following the course of the positive metals by uniting chemically with oxygen or other negative elements except under peculiar conditions, may be explained by the fact of its great density and the close aggregation of its component particles, which although attracting negative elements, are held together by forces too powerful to admit of dissolution.

10. Let us now remark tin, a highly positive metal; we shall find its conducting power extremely low, both for electricity and heat, the quantity of the latter evolved during passage of the current being six times that developed by silver, and there being consequently six times the resistance; but its density is only one-third that of platinum: in this case, therefore, we may conclude that its constituent particles are *much farther apart* than in platinum, or gold, or silver; in other words, that the spaces are much greater. This, however, does not improve the conducting power of tin; on the contrary, it is an extremely *bad* conductor. The same remarks will apply to zinc, to iron, and most of all to lead, in which the resistance is *twelve times that of silver;* and its conducting power for heat proportionally low. In all these metals the density is low, compared with gold or platinum, and consequently the constituent particles are wider apart; but the increased intervals do not augment their conducting powers, which, on the contrary, are very bad. Whereas, if we are to suppose that the *diminution* of the interstitial spaces exercises any influence upon conduction, it should follow that, inasmuch as lead has somewhat greater density than silver, it should have *better* conducting power, from the diminution of its spaces, and the closer aggregation of its particles; and that if the *augmentation* of the interstitial spaces is to exercise an influence, *lead* should be a better conductor than platinum or gold.

Tin and iron, in the *latter case,* should be better conductors than silver, copper, or gold; and in the *former* case, platinum should be a better conductor than gold, or copper, or silver. Is it not manifest, therefore, that since the increase and diminution of the spaces between the constituent particles of the above metals do not produce the expected results, *space really does not exercise any influence on electrical conduction one way or the other?*

11. The foregoing observations may be applied to all the other metals upon which experiments have been made with similar accuracy—including palladium, potassium, cadmium, and bismuth; and brass, although a compound metal, will be found to offer no exception. We thus perceive that there is an undeniable connection between the conducting powers of metals for electricity and heat—an evident relation between the heat evolved, and the degree of conducting power—between the chemical equivalent and the specific heat. Can there then exist a reasonable doubt, that the specific heat, and heat evolved, as also the specific electrical condition of the different metals, exercise a marked influence upon their respective conducting powers, and that those influences operate in creating the distinctions in substances which obtain for some the designation of conductors—for others, that of insulators—and that to *those influences,* and *not* to the *assumed* number of atoms in a given bulk, (concerning which questions must arise,) are to be mainly attributed the various properties and powers, not only of elementary, but also of compound bodies, in regard to the conduction and development of electricity? In what *peculiar manner* these influences operate in the production of the effects we have named, may be a subject of dispute and doubt; but we do not see how we can hesitate to recognize the *influences themselves,* where, in all our researches, they force themselves broadly and distinctly upon our consideration.

(To be continued.)

ON THE INCIPIENT DISENGAGEMENT OF ELASTIC FLUIDS.

By John Thomas Woodhouse, M.D.

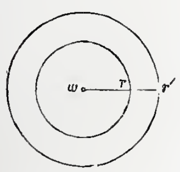
I have never seen or heard a satisfactory explanation of the well-known fact, that when a tea-kettle, with boiling water in it, is removed from the fire, the bottom is only moderately warm. It has been referred to like causes (substituting steam for vapour), as when spirits are thrown upon the skin, and a sensation of cold is produced, in which case heat is first given to the fluid, succeeded by a change in the state of the fluid.

This explanation appears to me defective and unsatisfactory; and I will now endeavour to show where it is defective, and supply the defect.

When the kettle boils, the water in it will raise the thermometer to 212° Fahrenheit; the fire is much hotter, and yet the hand which soon after touches it feels only a moderate warmth; in a short time the heat becomes intolerable—*i. e.*, of the same heat as the superincumbent fluid.

Now, admitting, when the heat of the bottom is becoming greater than 212°, that the water undergoes a change by its conversion into steam, and that the heat of the contents of the kettle is thus partly latent,—admitting that this would account for the bottom not indicating a greater heat than 212°, I contend it is unequal to explain why the bottom should be less than 212°: for the water is 212°, the steam under the ordinary pressure of the atmosphere is supposed to be 212°, and the fire which was under it more than 212°. The object of this paper is to explain why the bottom, immediately on its removal from the fire, should indicate a heat less than 212°, and soon after a heat equal to that of the water upon it.

Let w represent a portion of water. Let the sphere, whose radius is $w\ r$, represent the space occupied by the steam, into which this portion is converted by the communication of heat. The heat of the steam filling this sphere would be 212°; but, in explaining the object of this paper, I suggest that the heat of the steam may be less than 212°, and to establish this, I propose the following theory:—



I assume, that when a portion of water is converted from its fluid into its gaseous state, a sudden expansion, or what may be termed an explosion, happens; *i. e.*, supposing the steam in its quiescent state, and under the ordinary pressure of the atmosphere, would occupy the sphere, $w\ r$, at the instant of its conversion, by its elasticity or momentum of its particles, it proceeds to fill a sphere whose radius is $w\ r'$, which is greater than $w\ r$.

Now, according to the acknowledged doctrine of latent heat, when water receives heat which converts it into steam, the steam under atmospheric pressure would occupy a space varying with the quantity of caloric imparted to it. By the same doctrine of latent heat, if the same quantity of steam under the same pressure be made to occupy the greater space, $w\ r'$, it would require a greater quantity of caloric; and supposing the change from its filling the sphere, $w\ r$, to its filling the sphere, $w\ r'$, to be effected mechanically by its elasticity, it would be covetous of caloric, and would take it from any substance which touched it.

This theory will, I conceive, explain all the phenomena. A certain portion of water is converted into steam at the internal bottom of the kettle, which, in its quiescent state, under atmospheric pressure, would occupy the space, $w\ r$, but by its elasticity, or momentum of its particles, at the instant of its conversion it occupies the space, $w\ r'$, becomes colder than 212°, and thus takes heat from the bottom, reducing it below 212°, after the supply of heat from the fire has been removed. This reduction of heat can only happen whilst the water is boiling; after the water has ceased to boil, it soon communicates its own heat to the bottom, which explanation accords with the phenomena.

I cannot prove, by experiments, that when gas is liberated from its prison of a fluid or a solid, at the instant of its liberation it goes to occupy more space than it would do solely by the admitted laws of latent heat; but I suggest the following consideration, which may make this probable:—If a spring be fixed in a table, be bent towards the right, and afterwards released, it does not merely go back to the place where it will ultimately rest, but, by its elastic property, it would go considerably to the left, and would pass its resting-place several times before it be still. May not the spring held down by the finger on the right side, represent or bear an analogy to gas confined in a fluid or solid; and may not its proceeding to the left of its resting-place, represent its expanded condition immediately after it has gained its freedom?

I must now mention another circumstance, which is closely connected with, and comes in aid of, the present subject.

It has been observed, that on the first removal of any metallic vessel from the fire containing boiling water, the ebullition is increased. The solution may be this:—The cold air then surrounding and coming in contact with the outside of the vessel, by the subtraction of heat may cause its external surface to contract, and this may mechanically contract it internally, and so heat may be evolved. This explanation is nearly the converse of the previous one of the steam which has been given. There a chemical expansion first happens, followed by a mechanical expansion, by which heat is absorbed. Here, in the metal, a chemical contraction first happens, succeeded by a mechanical contraction, by which heat is evolved.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXI.

OF THE FACULTY OF SENSATION AND PERCEPTION, AND OF THE ORGANS BY WHICH MAN PERCEIVES THE PRESENCE OF THE EXTERNAL WORLD.

The whole organs of man may be divided into two great classes—namely, those by which he is nourished and grows and reproduces his kind; and secondly, those by which he perceives the presence of the external world, and the present and past order of things external to him, and by which he reacts upon them. This division of his organism or whole organization is not rigorous, and, therefore, not strictly philosophic; but it has been found to answer all practical, physiological, and even psychological purposes. It explains very beautifully how the first set of organs are chiefly occupied with merely building up the frame of the body, and have therefore been called *organic*, in contradistinction to the name given to the other or second set of organs, which, by reason of their seemingly belonging as it were exclusively to animals, have been called *animal*. Thus we have organs of organic life, and organs of animal life. The first includes the organs of

1. Prehension,......................	The lips.
2. Of Mastication,..................	The teeth.
3. Of Insalivation,.................	The organs forming the saliva.
4. Of Deglutition,.................	The cavity of the throat called the pharynx. This cavity may easily be seen by looking into the mouth; it leads directly into the gullet.
5. Of Digestion in its widest sense,..........................	In the stomach, small and large intestines.
6. Of appendages of the digestive tube,......................	Liver, spleen, and pancreas.
7. Of absorption of the chyle,....	The lacteal vessels.
8. Of circulation of the absorbed nourishing material — the chyle and blood,.............	The veins, the arteries, the heart.
9. Of nutrition, which includes in some measure the divisions 8, 7, and 6,............	The ultimate distribution of these vessels, including the absorbents.
10. Of respiration,.................	The lungs; to these may be added the kidneys, whose office is further to purify the blood.

Now these organs construct the animal frame, but they

do not bestow upon it that complete character usually called *animal;* by which is meant, the exercise of the organs of the senses, and of spontaneous motion from place to place, performed by the muscles and their appendages, the bones and joints; of perception of bodies external to ourselves; of reflection or thought, of which a specific or peculiar kind has been bestowed by the Almighty on every distinct species of animal, precisely adapted to its position in the great scale or scheme of creation; in short, those organs and their functions by which the animal frame may avoid what is hurtful to it, and approach and seek what is calculated to give it pleasure. The organs of voice and speech are here included, and the *division* may be arranged as follows:—

1. Organs of sensation, ...	The instruments of the senses: skin, tongue, nose, eyes, ears, and the nerves leading from these to the brain and spinal marrow.
2. Of perception and ratiocination with consciousness,..........	The brain.
3. Of perception and reflex action, but without consciousness,	The spinal marrow.
4. Of muscular action, with consciousness, ...	The muscles and certain nerves.
5. Of muscular action, but without consciousness,...........	Certain muscles, with the nerves supplying them.
6. Of voice,.........................	The larynx.

Thirdly, The reproductive organs are considered as entirely distinct from these two great divisions, and are considered apart, and merely in strictly professional works.

If the reader now consider the above plan even in any of its great outlines, he will immediately discover the happy adaptation of the functions and organs bestowed on each of the great divisions of living bodies, that is, animals and vegetables. Let him figure to himself the gigantic oak clothed or endowed with muscular power, and, in brief, with the power of motion such as animals possess! not fixed and rooted to the soil, but stepping out in straight lines, with or without reason, sweeping everything before it and rendering the earth immediately uninhabitable by man! A forest set in motion affrightening the inhabitants of the earth! On the other hand,nearly every animal, at least those possessing high endowments of such sensibility, possess invariably the power of withdrawing from what is hurtful; and poets have described with much, though fanciful truth, the fate of a human being shut up in the form of a tree, rooted to the soil, sensible and alive, but incapable of motion. Such a state, could it exist, would be the most pitiable and lamentable of all.

The organs of the senses, so valuable to all animals, but in an especial way to man himself, are usually reckoned five, from the days of Aristotle, the greatest Zoologist of all antiquity to the present day. Many very plausible arguments have been from time to time brought forward, endeavouring to show that the organs of the senses must be more numerous than five, if not in man, at least in some other animals; thus the surface of the human lips, the expanded integument of the arm of the bat, and the gelatinous, cylindrical shaped cavities found on the head of certain sharks, skate, and other cartilaginous fishes, have all been proposed as organs, exercising a new or a sixth sense, but the proofs of their being so, have never been fairly made out.

By virtue of the peculiar properties of their several nerves, the senses are said to make us acquainted with the states of our own body, and they also inform us of the qualities and changes of external nature, as far as they give rise to changes in the condition of the nerves; but in so far as regards the states of our own body, this is true only to a certain extent. Of all, or any of our internal organs we can have no notion through our unaided senses; and the phenomena of pain and of uneasy feelings, excited in us generally by a derangement or disorder of the internal organs,—such sensations of pain, as they are usually called, are probably transmitted to the brain, the seat of consciousness, by a peculiar set of nerves adapted for this peculiar use or purpose. Sensation, no doubt, is a property common to all the senses, but the *kind* of sensation is different in each; and thus we have the sensations of feeling or touch, of taste, of smell, of hearing, and of seeing. But it must be carefully kept in recollection that the human mind cannot perceive the external world in any way whatever; all that we do perceive is merely a property, or change of condition, of our nerves; now the imagination and reason are ever ready to make us believe that when we touch a body foreign to ourselves, the mind actually perceives the body so touched, whereas we merely perceive in the brain the change produced on the *extremity* of the nerve which has mediately come in contact with the material structure touched. It is the same with sight and with all the other senses, and hence arose the celebrated proposition of Berkeley, Bishop of Cloyne, "that as external agencies can give rise to no kind of sensations which cannot also be produced by internal causes exciting changes in the condition of our nerves, so no proof is derived through our senses of the actual existence of any material world." Before however proceeding further with the physiology of the senses, it is proper the reader have some idea of their mechanism or structure: and, first, of the *organ* of *touch or feeling.*

The sense of touch is not confined to particular parts of the body of small extent like our other senses, but, in its more limited sense, it is usually confined to the external integuments of the body, and in an especial manner to the extremities of the fingers and toes. In man these parts are peculiarly delicate and sensible, and the integument covering the fingers is obviously endowed with high capabilities; these it owes to the nerves which place it in connection with the spinal marrow, and through it with the brain.

STRUCTURE OF THE SKIN, AND OF ITS APPENDAGES.

The skin, or external integument, is accurately moulded upon the body; it conceals the inequalities and clothes the whole frame with great beauty, particularly in children and in women. It is extensile and also retractile to a certain extent; it is a sudorific or expellent and secreting surface, by which matters are removed from the blood which it were dangerous to retain in it, or even on the surface, for any length of time. Nature visits with much severity the habitual neglect of cleanliness, and of a due change of linen, by the production of numberless cases of cutaneous disorders, still so frequent in Ireland and Scotland; whilst the sudden stoppage of the perspiration gives rise to dangerous internal disorders. In a word, it is by no means improbable that the matter, thrown out at every moment, by, and from the skin, is of so highly poisonous a character, that its retention in the body may give rise to fevers, cholera, and to plague itself.

The skin has a free surface, and a fixed or adhering one; the free surface, or that exposed to the external atmosphere, is covered by a cuticle or scarf-skin, easily raised from it by blistering, and whose obvious use is to protect the more delicate nervous and vascular structures placed immediately beneath it. The particular nature of this scarf-skin or cuticle will be more particularly explained a little further on. Beneath the scarf-skin is a layer of tissue, deeply coloured in the negro and other dark races; it is called the *rete mucosum* of Malpighi, after its discoverer, a celebrated Italian observer. Its presence has been often questioned in the European skin, but to us it seems to be present, although but slightly coloured; in the Albino of all races, the colouring portion of this *mucous layer* is clearly wanting altogether, but still the mucous layer itself may be present even in the Albino. The presence of this coloured layer of the integuments in the negro, must serve important purposes in his economy, for we observed that an Albino girl, born of Caffre parents, that is of jet black parents, whom we saw at Van Aards on the Grootevisch Riviere, in Southern Africa, and on the borders of Kafferland, suffered nearly as much from the heat as any European; that is, the exposed parts

of the skin were blistered by the action of the sun's rays as in ourselves.

Beneath the *rete mucosum* is the true skin, the *dermis* or *corion*. This is of very considerable strength and even thickness, especially on the back; it is of a close, dense interwoven tissue, and abounds with nerves and blood vessels; its connection with the filamentous or cellular tissue beneath it, is of course intimate, and necessary for its vitality; it is here, of course, that the fixed surface of the skin exists.

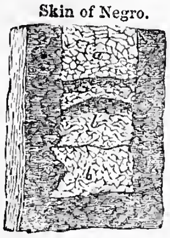
It might be supposed sufficient for the purposes of this work, to have described the skin or the integuments of the body as above; but it is from a want of more minute elementary knowledge, that many popular notions are not only incorrect but absolutely hurtful. The very term *surface* leads many to suppose that the mere integuments cannot be of much consequence, at least anatomically and physiologically considered. Now this is a great error, for the robe or external covering of all animals has characters of the greatest constancy, and as accurately define the animal as any other structure whatever.

On the free surface then of the integuments we observe folds, wrinkles, and furrows; those in the palm of the hand were made the subject of a silly art called Palmistry, derived from oriental nations—from races of men whose minds were either not properly educated, or who from nature have received a bias towards a belief in mysteries and follies of all descriptions—who have no natural love for *scientific truths*, and who cannot be made to comprehend the true physical relations of cause and effect.

These folds or wrinkles are of several kinds; the larger, are observed around the joints, the smaller, over the whole surface of the skin. The folds called wrinkles are produced by the action of muscles placed immediately beneath the skin, as on the forehead and temples. The wrinkles of old age, in various parts of the body, are produced by emaciation and the loss of the retractile power of the dermis or true skin. A difference in colour is, however, the most remarkable circumstance in the appearance of the integuments of men, and has strongly arrested the attention of all observers. The negro race has existed, as it now is, from the most remote antiquity, as may be proved by a reference to the paintings on the tombs of the Egyptian kings.

If a portion of the human integuments be divided and removed from the body, so that the cut edge may be examined with a magnifying glass, certain structures will be seen, which, for the convenience of description, may be arranged under three heads; namely, epidermic parts; 2d, dermis or corion; 3d, subcutaneous cellular and adipose layer. We shall speak of these layers in the order just enumerated.

Fig. 1.
Skin of Negro.



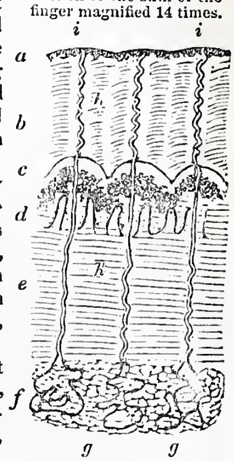
a, The cutis, dermis, or true skin; *b'*, the pigmentum, or colouring matter of the lymphatic network; *b*, the epidermis or cuticle.

Anatomists have been forced to have recourse to the skin of the whale, the elephant, and of many other animals, in order to determine by analogy the nature of parts, which, from their tenuity and delicacy, could not be well made out in the human skin. 1. The epidermis or cuticle, marked *b*, is the outermost of all the epidermic parts of the integuments; it is to it that the term scarf-skin is always given; it is semi-transparent, and in some measure a horny layer moulded upon the surface of the true skin, over all the papillæ or nervous and vascular prominences, like a coat of varnish, effectually protecting the tender and delicate surface from the action of external agents. The epidermis is represented at *b* fig. 1, and *a b* fig. 2; but the reader, rightly to understand its structure, and that of all those to follow, must handle and examine them for himself; otherwise, extremely erroneous notions are sure to be the result of studying or learning any material object from books and figures alone, neglecting the invaluable and indeed essential knowledge we derive through the use of the fingers. The very instrument, indeed, which we now examine, the instrument of touch, is that by which and through which, we derive by far the greatest part of all sound knowledge of the material world.

When the epidermis or scarf-skin is stripped off, its inner or deeper surface is observed to be covered with little pits or depressions; in the skin of the negro, the colouring matter occupies these little pits, but still is said to be found in greater abundance between the nervous papillæ than upon them. But the scarf-skin seems here also to be somewhat coloured in the negro.

When the scarf-skin is being removed from the parts below, a great number of fine transparent filaments may be observed, which are torn through in separating the one from the other; these filaments are supposed to be vessels which pour out the perspiration, whilst others have supposed them to be merely the lining membrane of other tubes, more lately described.

Fig. 2.
Section of the skin of the finger magnified 14 times.



a b, The epidermis; *c*, colouring matter or pigmentum; *d*, rete mucosum of Malpighi; *e*, the dermis or true skin: *f*, subcutaneous and adipose tissue; *g g*, sudoriferous glands; *h h*, spiral canals going from these glands, and terminating on the surface at *i i*.

A great objection to this view of the filaments alluded to above, is that they may be seen with the naked eye, whereas the spiral tubes of the sudoriferous glands, whose lining membrane they have been supposed to be, can only be seen with a good glass; fifty of these orifices open within the space of a square line.

Beneath the epidermis, properly so called, may be seen, in the above figure, the other epidermic parts which are still called rete mucosum, pigmentum, &c. These parts which much resemble the scarf-skin, form sheaths over the nervous papillæ, as may be seen in fig. 2.

The epidermic parts are of vast thickness in the skin of the whale, and it is on it that the greater number of discoveries have been made, with reference to the integuments generally. All these layers are insensible, and by some are called inorganic; they are probably merely not essentially vascular. Thin, flattened, horny corpuscles are deposited on the surface of the true skin; these hardened on the surface form the epidermis properly so called, while the corpuscles beneath form the pigment and rete mucosum. Fine scales are continually being thrown off by the epidermis and replaced by the subjacent ones.

The pigment seems to exist in all varieties of the human race, varying however greatly in the depth of colour; it appears *partially* even in the white races, and has been observed in them to be fully as dark as in the negro, but confined merely to a small portion of the skin; hence has arisen the opinion, first maintained by Azara, that such accidental varieties might extend, become hereditary, and thus explain the colouration of the negro and other dark races; this opinion is merely hypothetical.

The dermis, or the true skin, is situated beneath all those parts, and is properly the basis of the integument. It varies very much in thickness, being thickened usually on the back, and over the cranium; also on the palms and soles of the feet. On the deep surface—that namely by which it adheres to the living structures beneath it—a number of conical depressions may be observed; into these project masses of fat. When the skin is separated extensively from the parts beneath it, it is apt to slough or die, for a very obvious reason, being then cut off from the sources supplying it with blood. When examined microscopically, it is found to be cellular and fibrous, and is resolved into gelatine by boiling, and by tanning is converted into leather. The elasticity of the dermis seems to depend more on the arrangement of its texture, than on the intimate nature of that texture. The papillæ are those

eminences seen on the surface, and which in the hands and feet are arranged in rows; they are nervous and vascular, and seem analogous to those much larger, visible on the tongue. On the outer surface of the dermis lies a network of exceedingly fine lymphatic vessels, discovered by the celebrated Mascagin. The presence of these vessels explains the absorption into the blood of fluids or solids, rubbed through the epidermic parts.

Beneath this important part of the human integuments, is the layer called the subcutaneous cellular and adipose tissue; in young persons, and especially in women, the fat forms a complete layer under the skin, sometimes of very considerable thickness, giving to their forms that agreeable appearance, indicative of youth and health; its usual absence, or at least partial deficiency, allows in man the form of the skeleton, muscles, and tendons, to be more especially observed. In some animals, called pachydermatous or thick-skinned, it also forms a remarkable subcutaneous layer, as in the pig, hippopotamus, and probably the tapir. In whales, the layer of fat forming the blubber is not confined to the subcutaneous cellular tissue, but extends deeply into the tissue of the skin itself. Various uses have been assigned for its abundance in whales, but none of them are at all satisfactory.

APPENDAGES OF THE SKIN.

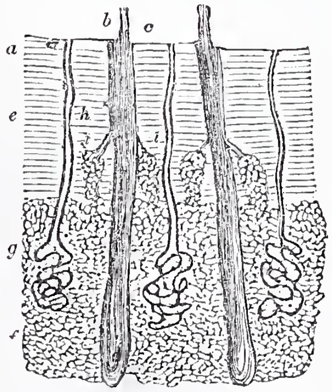
Before making a few concluding remarks on the physiology of touch, I shall briefly describe the appendages of the human skin: these are—1. the sebaceous follicles; 2. the nails; 3. the hair.

The *sebaceous follicles.*—These consist of small pouches or bags, about the size of a millet-seed, lodged in the substance of the dermis, opening externally by very small orifices, visible, however, in some persons to the naked eye. From these orifices an unctuous matter is constantly poured out upon the surface of the skin, assisting in preserving its flexibility; on the sides of the nose and face, generally, the sebaceous matter often collects into little hardened masses, discoloured on the surface. These may be squeezed from the bag or cavity by pressure, and are then mistaken for worms. Microscopic worms are no doubt also found in various follicles, but they are totally unlike the sebaceous secretions.

The follicles open in two ways; either on parts of the surface where there are no hairs, or into the hair follicles, as may be understood from the following figure.

Fig. 3.

Section of skin from head, magnified 14 times.



i i, Sebaceous follicles; *c*, Hair follicles; *g*, Sudoriferous glands; *f*, Subcutaneous cellular and adipose tissue; *e*, The dermis; *a*, The epidermic parts; *b*, The projecting parts of the hair.

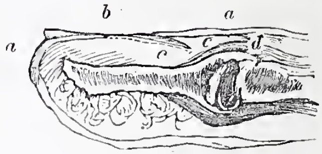
It is generally admitted that the more common description of wen, frequently found on the scalp, is formed merely by an accumulation of the albuminous and fatty matters collected in one or more of these follicles.

Of the nails and hair.—In man these are but little developed, compared with almost any other animal of the same great class. In most hot-blooded quadrupeds, the system of the nails and hair covers nearly the whole surface of the body; and even in the elephant and hippopotamus, where the hairs are scanty, their place is amply supplied by the thickness of the epidermic parts. So also in whales. We shall first speak of the nails.

The human nails, more especially those of the fingers, are hard, flexible, elastic, and translucent. When well-formed they have a specific elongated character, but in many persons they are ill-formed, and approach more or less to the form of the claw, that is, become pointed. For the sake of description, the nail is divided by anatomists into *root*, *body*, and *free portion.* The root is covered on both surfaces, and is only seen on dissection; the body is covered only on one surface; the free portion is free on both sides. This free portion has a tendency, when left to grow to its full extent, to become incurvated, and in consumptive persons remarkably so, caused probably by the atrophy of the subjacent soft parts.

Fig. 4.

Representing a vertical section of the extremity of one of the fingers.



d, The dermis; *c c*, Duplicature of skin; *b*, Body of the nail; *a*, Epidermis.

The root is about a fourth the length of the body of the nail, and is its thinnest part; it is received into a fold or duplicature of the skin, *c c*, to which it is attached by both surfaces; but these attachments are but slight, compared with that by which the body of the nail is fixed to the sensitive parts beneath it. It is this connection chiefly which renders the tearing of the nails forcibly from their roots so very painful an operation; an operation, however, which is sometimes required.

The nail is separated from the bone by a very thick portion of the dermis or true skin, exquisitely sensible, and very vascular; a fine part of the nail, at the part nearest to the skin, is called the *lunula*; it is somewhat crescent-shaped, and is supposed to show a slight discoloration even in those mestizzoes, whose blood might otherwise be supposed to be pure. Authors are not agreed as to the ultimate connection of the epidermis with the nail. They are, however, in their nature strictly analogous, also in their chemical composition.

Nails then are not vascular parts, but are the products of secretion, and are also, as it were, excretions; a diseased nail is produced merely by a disease in the part producing it. They have been compared to the teeth, and are no doubt a substance of precisely the same horny nature, as the nail takes the place of the teeth in the whale; but still the analogy is remote. The young whale before birth has teeth in both jaws, although they never become properly developed; that is, in whalebone whales. Whalebone then is merely a substitute for, but not identical with the teeth in any sense whatever; and they have not at all the same chemical composition. The nails grow continually in length, as may be proved by a very simple experiment. In civilized life they require attention and even care; in savage life, all such matters are adjusted by nature.

ILLUSTRATIONS OF MECHANICAL DRAWING.

CHAPTER VI.

In the last article, a general explanation was given of the nature of geometrical projections of machinery, of the principles upon which they are, to a certain extent, derivable one from another, and of their peculiar adaptations to the purposes of mechanical representation.

Our business will now be, to render familiar to the student the methods of delineating mechanical objects in particular, to present detailed accounts of the processes of geometrical projection, and so to facilitate his progress in the art, as to enable him to lay correctly down upon paper any combination of mechanical ideas which he may wish to preserve.

The first thing to be attended to, in contemplating the execution

of a drawing upon paper, is to determine the *scale* upon which the drawing is to be made. By the scale, we mean the proportion which the actual dimensions of the drawing bear to those of the machine which it represents. Drawings are made on various scales, according to circumstances, depending upon convenience for portability and reference, and also upon the actual minuteness or largeness of individual parts of the machine. The mechanism of a watch, for example, is so minute in its actual dimensions, compared to the mechanism of some other more powerful machinery—as, for instance, a steam-engine of 20 horse power—that while no one would hesitate to make a drawing of the former on a scale of equal magnitude for the purpose of practical reference, the latter, to be brought within the compass of an ordinary sheet of paper, would require to be drawn on a scale of reduced magnitude, to the extent, say, of one-twelfth of its lineal dimensions. An ordinary turning-lathe, and other tools, might be drawn one-sixth of their original sizes; and a suspension-bridge must be reduced, in a drawing, two or even three hundred times its real size. Various examples of all kinds are given in this work.

These remarks point out the necessity of suiting to circumstances the scales to which machines are to be drawn. But, again, it is of frequent occurrence that the same machine contains parts of considerable magnitude of outline, and others of comparative minuteness, so that a scale which might be quite suitable for the larger parts would involve the smaller in confusion, or would render them, at least, unavailable for conveying more than a general idea of their form. This circumstance, when it happens, renders necessary *detail drawings*, or separate drawings of those individual minute parts upon a larger scale than the whole machine is done to, or even *full-size* drawings when the parts are of importance and not large.

Hitherto our remarks have related to paper drawings. In regard to *working drawings* for the guidance of workmen, they are commonly all done upon boards of wood, full size, in detail, even to the largest individual piece of machinery.

The *scale* of a drawing always bears reference to the proportion of its *lineal* magnitude to that of the machine. It is of importance to bear this in mind, as, otherwise, one is apt to be deceived in judging of the scale of a drawing. Besides lineal magnitude, in short, there is also *superficial* magnitude, and it is well known that the areas of similar figures are as the squares of their lineal dimensions; from which it follows, that by reducing the lineal magnitude of a machine in any given ratio, the superficial magnitude is decreased to a much greater extent. For instance, in fig. 8, page 299, suppose the figure, $a' c'$, which is therein depicted, to represent the surface of the body, $a\ b\ c$, full size; now, let its sides be divided in two equal parts, and the points of division joined by lines parallel to the sides of the figure as is there done, it is obvious that each of the four subdivisions of the figure thus made are similar to it, and would correctly represent it. Now, in this case, it is also obvious, that while the lineal dimensions of that figure would be reduced at the rate of one-half, its superficial dimensions would be reduced one-fourth. Thus, while the scale of the smaller figure is denominated a one-half scale, it really reduces the area four times. A scale, too, is frequently designated by the inches or portion of an inch of actual length, with which its parts are drawn to represent one foot length of the machine. Thus, a one-half scale is also termed a *six-inch* scale, as six inches are one-half of a foot; a scale of one-sixth is also called a two-inch scale, and a scale of one-twenty-fourth, a half-inch scale, since one foot contains half an inch twenty-four times.*

Having fixed upon the scale of the drawing, it is to be laid down for use on any convenient spare part of the sheet, when not constructed separately. To do this, all that is necessary is to draw a line, and set off upon it a convenient number of "feet" of the scale, and to divide one of these feet at either end into inches, and divide still further, if thought necessary, into parts of an inch. The feet ought then to be numbered for easy reference.

In the next place, a rough estimate ought to be formed of the amount of space which the drawing will occupy, whether consisting of one or more views. For this purpose it is sufficient to take the extreme dimensions of the machine in the planes in which it is to be drawn. These will give us the portions of space which the drawings must occupy; and thus the positions of the several views may be arranged beforehand. It is proper to lay the drawing as nearly in the middle of the sheet as may be. In general, when one or two elevations and a plan are to be drawn, the elevations are drawn first, as they usually convey a fuller idea of the machine, and thus the dimensions can be more readily transferred to the plan. Similarly, of the two elevations, the side elevation is done first, as it usually exposes a greater number of parts than the other. On the other hand, the plan is first made where any geometrical operations are necessary towards the forming of the elevation. But, for the same reason, it is sometimes most convenient to draw two or more views together, though this is seldom done when a drawing is taken directly from a machine, and still less when it is merely copied from another drawing, unless indeed there occur parts of the same form in all the views, when of course, by one setting of the instruments, there may be several dimensions marked and lines drawn.

There is one other point yet to be explained in regard to the execution of *outline drawings*. By an outline drawing is meant such as consist simply of the lines employed to indicate the form of the subject of the drawing. The *appearance* of the subject which is produced by the variety of light and shade with which it is naturally invested, is a matter which is not recognized in outline drawings; for example, the roundness, the flatness, or the obliquity of individual surfaces, is not indicated by the mere lines which tell of their form, although it may often be inferred from the correspondence of different views of the same part. To understand an outline drawing, the exercise of judgment is necessary in connection with experience of the general rules of mechanical construction in detail. There is a method, however, of bringing out, to a considerable extent, the meaning of drawings in outline, by rendering comparatively stronger those lines which indicate the contours of surfaces lying in the shadow. It has the advantage, too, of greatly improving the appearance of the work. The strong lines, to produce the best effect, ought only to be laid upon the sharp edges at the summits of salient angles. It is inelegant and improper to strengthen such lines as merely indicate the limits of rounded surfaces, as these are only apparent, not real contours, arising from the curvature of the surfaces, and the particular point from which they are viewed. For example, a sphere, from any point of view, would be represented by a circle. There is an obvious necessity for such a line to represent the form of the object, though the proper office of lines is to represent the intersections of planes, whereas the surface of a sphere is a uniform curve. Bounding lines, therefore, for curves in projection, ought to be drawn as finely as possible. As another example, take a cone—in this instance, the only edge or angle is the contour of the base, which is circular—yet, in taking a side elevation of the figure, two additional lines are necessary to point out the taper and height of the cone.

This distinction further offers the considerable advantage of enabling us to ascertain the curve from the flat surfaces. But to determine at a glance the meaning of all the *shade-lines*, as they are termed, we must be aware of the direction in which the light is supposed to fall upon the machine, thereby to know also the determination of the shadows. The investigation of this subject in detail must be reserved for a future period. In the meantime, sufficient for our present purpose will be stated, with the assistance of the following diagrams.

It is necessary, for the sake of the explicitness of the drawing, that in the first place the light be supposed to fall upon the object in parallel lines, so that all the parts may be shade-lined, according to one uniform rule; secondly, that the light should be supposed to fall upon the object neither in a vertical nor in a horizontal plane, but obliquely to both; for in this arrangement, both the horizontal and the vertical forms may be relieved by shade-lines. Our meaning may be illustrated by reference to fig. 8, p. 299. Here the point, d, in relation to the body, $a\ b\ c$, has a position which is not in the same plane with any of its faces—it lies obliquely to all of them; and if a line were drawn from that point to any point in the body, $a\ b\ c$, it would show the obliquity. If this line be produced towards the upper side on the right, it might represent the supposed direction of the light. To distribute, then, the shadows equally, the light is commonly supposed to fall in directions forming an angle of 45° with both the horizontal and the vertical, and as there are two vertical planes of projection, the light should also be oblique to both of these. In short, for elevations, the light should come as it were from towards the upper right-hand corner of the sheet of paper, supposing it square, but also making an angle of 45° with the surface; and for plans, other circumstances being the same, it should come from the lower right-hand corner.

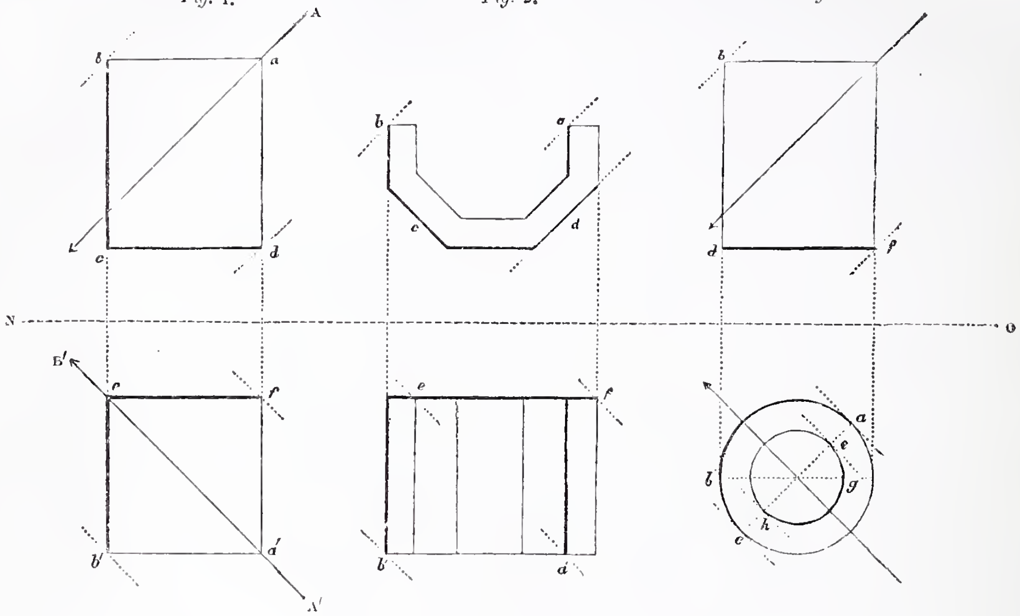
To illustrate what has been stated, let $a\ b\ c\ d$, and $a'\ b'\ e\ f$, fig. 1, represent the elevation and plan of a solid rectangular body, N O, being the ground line. Suppose the direction of the light in both views to be represented in projection by A B and A′ B′, then it is evident that these lines form the angle 45° with

* We would take this opportunity of recommending Holtzappfel's "Ordinary Drawing Scales," from one quarter-inch to three inches, which are executed upon slips of stout card paper of convenient length, and which are of great utility for the doing of scale drawings.

the line N O. By drawing the parallel lines at b, d, b', f, so as to embrace the extreme contour, we can readily perceive the nature of the effect of the light in striking upon the body. It falls upon three faces of the body—namely, the two vertical faces $a'\ b'$, or $a\ b\ c\ d$, $a'f$ and $a'\ b'\ e\ f$ or $a\ b$, consequently, the intersections or lines at which these planes meet ought to be lightly drawn—namely, $a\ b$ or $a'\ b'$, $a\ d$, and $a'f$. Again, the lateral planes at $b\ c$, $c\ d$, $b'\ e$, and $e\ f$, are obviously in the shade, no light falls upon them directly; to express the difference then, we strengthen the lines $b\ c$, $c\ d$, and $b'e$, ef, as being the lines of separation between the light and shade. The distinction made in the disposition of the shade-lines gives the advantage of pointing out whether the figure be an elevation or plan.

In fig. 2, $a\ b\ c\ d$, and $a'\ b'\ e f$, are an elevation and plan of a body less simple in form than the one last examined. The direction of the light is thrown the same as in the other. The lines composing the interior and exterior contours in the elevation are parallel to each other, and thus the parallel parts will contrast with each other. It is obvious that the portion of the exterior from b by c to d is in the shade, while the rest is light, and that the inverse is the case with the inner edges. A peculiarity, however, occurs at d, for here the edges, inner and outer, are parallel to the direction of the light. It is plain that the surfaces which come up to these edges cannot be so strongly shaded as another surface, at c for instance; it is no less evident that they cannot be so bright as those which receive the light more di-

Fig. 1. Fig. 2. Fig. 3.



rectly. Such lines ought therefore in general to be but slightly different in strength from the light lines, though sometimes it is necessary to make them heavier to relieve the drawing better.

The last particular example which we shall require to bring forward at this time is the projection of a round body such as a cylinder, fig. 3. In the plan, if we draw two lines at a, c, parallel to the direction of the light, and touching the exterior of the cylinder, the semicircle $a\ b'\ c$ will denote that part which is thrown into the shade, and ought therefore to be strengthened. The points at a and c are, like the edges at d, fig. 2, parallel to the light, and the contour on both sides gradually recedes and advances to the light. The thickness of the line should, therefore, be rather gradually diminished at the points a, c, as it would besides appear awkward to stop the shade abruptly on a circle. In the elevation, the base-line $d\ f$ alone should be shaded, and $b\ d$ left light, notwithstanding that it is situated in the part deprived of light, for, as was observed before, it expresses simply the limits of the boundary curve incidental to the view taken of the body; it is not a real contour.

If again, we suppose the cylinder to be hollow, so as to present in plan the circle $e\ g\ h$ for the interior contour, then the semicircle $e\ g\ h$ expresses the shady side of the interior, as the light strikes directly upon the opposite semicircle. It is to be observed that the positions of the shade on the exterior and interior surfaces are reversed in reference to the line $a\ c$.

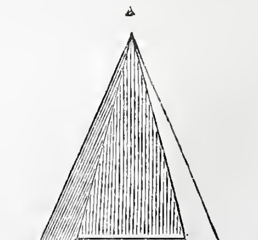
The preceding examples illustrate every case of shade-lining that occurs in outline drawings. The effect of this method is enhanced by proportioning the thickness of the lines to the depth of the surfaces to which they belong, below the original surfaces from which the shadow arises, which will be shown in subsequent examples.

We are aware that the customary practice is to throw the shadows to the right, as if the light came from the left; but we recommend the contrary method, as it does equally well for outline work, and is much more convenient in the execution of finished or shaded drawings, as will be afterwards shown.

Before proceeding further, we shall make the following explanations. There will be two species of dotted lines employed in the illustrations that follow, answering two purposes; first, lines intended to represent edges which are out of view will consist of a succession of short equal lines, as N O, fig. 1; and lines which are employed about the figures, for the purpose of facilitating the construction of the different parts of them, will consist of a succession of points, as $a\ c$, fig. 3.

Let us now enter upon the particular delineation of a regular hexagonal or six-sided pyramid, represented by fig. 4. On inspecting the figure, there appear to be two distinct geometrical views necessary to convey a full idea of the form of the pyramid; an elevation, namely, representing the part A B C, which constitutes the sides of the body, and expressing the height; and a plan of the upper surface, which shall also express the figure of the base B C.

Fig. 4.



Now, it is to be observed, that this body has an imaginary axis or *centre-line*, about which the same parts are equally distant. This is the essential characteristic of all *symmetrical* figures, or such as may be supposed to consist of two halves of the same form joined together. A cone, for instance, may be cut in two halves of the same form, down through the axis or *centre-line*, and so also may the pyramid. Draw then with the pencil a

light ground line, N O, fig. 5, across the sheet, and at the most convenient point, H, make a perpendicular or vertical line, *a b*. The first of these lines will contain the base of the pyramid, and upon the second, as a centre line, the figure is to be drawn. In this example it will be necessary, in order to determine the

Fig. 5. *Fig.* 7.

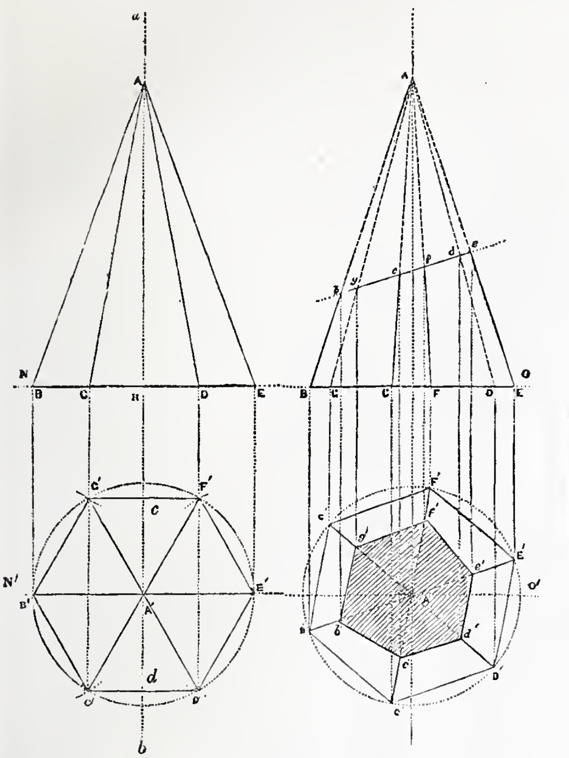


Fig. 6. *Fig.* 8.

several points in the base, first to draw the plan of the figure. For this purpose take any point A′, fig. 6, in the line H *b*, at a convenient distance from H, and draw through A′ a horizontal line N′ O′, then the point A′ may be taken for the centre of the figure in plan. Round this point describe a circle, with a radius equal to the side of the base, the circumference cutting the line N′ O′ in B′ and E′. With the same radius, and upon these points as centres, describe arcs of circles cutting the circumference in other four points. All the six points being joined together, the figure B′ C′ D′ E′ F′ G′ of the base of the pyramid will be formed ; and if the lines B′ E′, C′ F′, D′ G′, be drawn, they will all pass through the point A′, and will represent the angles or edges of the pyramid.

If this operation has been correctly done, the opposite sides of the hexagon ought to be parallel. This will be readily tested for the sides C′ D′, F′ G′, by applying to them the edge of the square. If these be right, the others will be right also.

But this suggests another method of drawing the figure. Having drawn the circle and found the points B′ E′, then from one of these points, B′, describe circular arcs with the same radius, cutting the circle in two points e′, G′; draw the parallel lines C′ D′, G′ F′, with the square, meeting the circle in the other two points D′, F′, and having thus formed the angles of the base, join the other four sides as before.

This second method, however, is not so expeditious as the first, unless the triangle of 60° (fig. 5, page 299,) be employed. In this case, having found the points B′, E′, the business is simply to slide the triangle along the edge of the square, and draw the lines B′ G′, D E′, off the edge of it, lying one way, and the lines B′ C′, E′ F′, lying the reverse way, then to draw G′ F′ and C′ D′ off the edge of the square. At the same time that the oblique sides from B′ and E′ are drawn, the diagonal lines C′ F′, D′ G′, which are parallel to them, may likewise be drawn. It is obvious that unless the draughtsman take the points correctly, the angles of the figure will not turn out as they ought to do.

But again, there is yet another mode of drawing the hexagon by means of an interior circle, upon which the sides of the figure are drawn as tangents. Thus, the straight line *c d* being the shortest measure diametrically across the figure, draw a circle with the radius A′ *c* or A′ *d*. Then it is evident that by applying the edge of the square to the upper and under points of the circle at *c* and *d*, the two sides e′ D′, F′ G′, may be drawn; and in the same way, by sliding the triangle upon the square till its edge touches the circle at the other four points, the remaining sides likewise may be drawn.

By means of the plan thus drawn it will be easy to execute the elevation of the pyramid. If we conceive the body as represented in fig. 6, turned quarter round, the apex A′ being moved towards H, there will be presented the elevation of the side A′ B′ C′ D′ E′ ; consequently, the position of each of the summits of the angles B′, e′, D′, E′, upon the base line N O fig. 5, will be had by drawing lines from these points parallel to the centre line A A′. Then from the point B′ draw the vertical B′ B, from the point e′ the vertical e′ e, and so on for the others. The intersections of these lines with the ground line N O will be the projections of all the summits of the angles of the base, which will therefore be represented in the elevation by B C D E. We have only now to fix upon the position of the apex A′ of the pyramid, fig. 6, in the elevation fig. 5, which is easily done by setting off upon the centre line its height H A above the base, or by describing an arc of circle upon B or E, with a radius equal to the length of one of the edges, cutting the centre line at A. From the point A draw lines to the points in the base, A B, A C, A D, A E, and the elevation will then be complete.

The apparent length of the lines in the pyramid are all drawn in the elevation, but the three sides A B, A E, e D, alone are seen full length, as they are all parallel to the surface upon which they are projected, while the sides A e, A D, appear shorter than the others on account of their being inclined to the surface of the drawing, which is also the case with B e, and D E in the base line.

It is clear that the lines e′ e, D′ D, pass through the points G′, F′ ; thus these points likewise are represented in the elevation by the points C, D, and that figure may be considered as an elevation of the part of the plan A′ B′ G′ F′ E′.

To delineate fig. 5 without the aid of fig. 6, we have only to find the points B, e, D, E ; this is done at once by setting off from the centre line the distances H B, H E, each equal to the length of the side of the base, which is the radius of the circle in the plan, and by setting off also H C, H D, each equal to half the side of the base. These points may then severally be joined as before to the point A.

Again, suppose the upper portion of the pyramid cut away by a plane perpendicular to the plane of the elevation, and inclined to the horizontal or ground line. The *section* of the pyramid as it appears in the plan, would be found in the following manner :

For the sake of variety, let the position of the pyramid be such that none of its sides in the plan are parallel to the ground line. Draw, as before, a centre line, A A′, figs. 7 and 8, cutting both the horizontal lines N O, N′ O′; then we have the intersection A′ for the centre of the plan as before, from which is drawn the circle embracing the tops of the angles of the base. But as none of the sides of the figure are parallel to the ground line, draw a diameter B′ E′ at an angle with the line N′ O′; upon B′ E′, construct the figure of the base as before, and join the opposite corners to obtain the horizontal projections of the edges. Then, as before, draw off parallel lines to the ground line, fig. 7, from the corners of the base, fig 8, giving for the vertical projection of the base, B G C F D E upon the ground line. Having marked off the height A of the pyramid, draw lines from it to the several points, to complete the elevation.

In the construction of fig. 8 there occurs an opportunity of using the pair of triangles represented in figs. 6 and 7, page 299. Thus the piece *b*, fig. 7, being set with its upper edge coinciding with line B′ E′, let it be slid down on the edge of the piece *a*, which is fixed against it, into a position such as that indicated by the dotted lines, so as to be clear of the circle. Then upon the upper edge adjust the triangle of 60° to the points B′ and E′, in its two positions, to draw the four sides meeting at these points, and finally join e′ D′ and F′ G′.

Now, the cutting plane represented in the elevation by the line *b e* will cut the solid so as to form a section of six sides, and it is obvious that in the elevation the summits of the angles of this section will be just in the intersections of the line *b e*,

with the edges of the solid at *b, c, d, e, f, g*. If then from the point *b* is drawn the vertical *b b'* to the line B' A', the point *b'* will be the horizontal projection of one of the angles. Having obtained the other points, *c', d', e'*, &c. in the same manner, they will form, when joined, the hexagon *b' c' d' e' f' g'*, which will be the plan or horizontal projection of the section.

It is to be expected that the section, as it appears in plan, should be irregular, being formed by a plane which is inclined to the base of the pyramid. The edges F *f*, and G *g*, have been drawn in broken lines as not being seen, as also for the same reason that portion of the pyramid which lies above the plane of section. There is introduced in the plan, fig. 5, the ordinary method of expressing sections, which is by filling up their interiors with a quantity of parallel lines closely drawn at equal distances. The same mode of distinction will be used in succeeding figures, when occasion requires.

THEORY AND PRACTICE OF DYEING.

Chapter IX.

VEGETABLE DYE-STUFFS.

I.—MADDER.

This substance rivals indigo in value as a dye-drug, both from the beauty and permanence of the colours it produces. It is the root of a plant or shrub, named the *rubia tinctorium*, that grows naturally in the Levant, Italy, southern parts of France, and in Switzerland. It is cultivated to a great extent in Holland. Its culture has been often attempted in England, but without success. This plant was well known to the ancient Greeks and Romans, and was much used by them as a dyeing agent, and in medicine.

It is the root of the madder that is used for dyeing; it requires to be three seasons in the ground before fully grown. Of the practice of culture, we are not acquainted in this country. The roots when fully grown are about the thickness of a common quill. When properly dried, if they are broken or cut with a knife, they present to the eye a red yellowish colour, which assumes a dense brownish red colour when moistened; but the more yellowish the root appears when dry, the more available is the colouring matter. Madder when fresh in the root, and after being cut and ground to powder, in which last state it is used by the dyer, gives off a heavy sweet smell with somewhat of an earthy flavour. Madder of a bitter, stale, or sour smell, is invariably of inferior quality.

Madder has been subjected to a great many chemical inquiries, the study of which is highly useful to those who use this dye-drug in their operations. The first investigation into the chemical properties of madder, led to the discovery of two distinct colouring matters which it contains; one yellow, which is very soluble in cold water, and was named *Xanthin*; the other red, moderately soluble in hot water, and is extracted from madder in considerable purity by sulphuric acid—it is called *Alizarin*. Several methods of extracting alizarin by sulphuric acid have been proposed; the following is probably the most easily practised. "One pound weight of madder is mixed with an equal weight of concentrated sulphuric acid, the vessel so closed up that no heat is evolved, and allowed to stand in a cool place for three or four days. By this process, all the constituents of the madder are converted into charcoal, except the alizarin. When this charring process is completed, it is carefully dried, and then digested in alcohol, which dissolves the alizarin, and leaves the charcoal. The solution may now be diluted with water, and the whole put into a retort and kept at a heat of 170°, the beak of the retort being connected with a receiver, the alcohol distils over, and is recovered; water and alizarin remain in the retort, which being filtered, the alizarin remains upon the filter in a state of great purity. It is of a beautiful red colour, and communicates the same colour to boiling water.

Alizarin is soluble in turpentine, naphtha, and fat oils. Chlorine turns it into a yellowish brown; sulphuric acid dissolves it, and at the same time enlivens the colour; muriatic and nitric acids both dissolve it, changing the colour from red to yellow; Alkalis gives it a violet colour; alumina forms with it a deep red brown precipitate; oxides of tin the same. Phosphate of soda has a very powerful attraction for alizarin, hence the reason that those animals who take madder into their system, have their bones dyed of a red colour. This fact has been long known to practical dyers who use madder in their operations.

From the above facts, it was conceived that alizarin constituted the true colouring matter of madder; and means were then adopted to separate this colouring matter from the vegetable, and use it pure; but it was afterwards found that a fixed dye could not be obtained by pure alizarin, and it therefore was not the true colouring matter of madder. This led to further investigations and further discoveries respecting these colouring substances, from which it appears that madder contains five different colouring matters which have been named,—*madder purple, madder red, madder orange, madder yellow*, and *madder brown*.

Madder purple is obtained by the following process: The madder is washed in water at about summer heat, then boiled in a strong solution of alum for an hour, the clear liquor is afterwards decanted, and sulphuric acid added, which precipitates the madder purple with a number of impurities. These are removed by washing with boiling water, then with pure muriatic acid, and afterwards dissolving in alcohol. Madder purple is soluble in hot water, and if pure, gives the water a dark pink colour. If the water contain lime, a part of the madder purple is precipitated as a dark reddish-brown substance. Cotton saturated with the acetate of alumina is dyed a bright red, if the quantity of madder purple be not in excess; when it is so, the colour will have more of a purple cast. A boiling solution of alum forms with the madder purple a cherry red solution. Caustic potash forms with it a fine yellowish red colour. Carbonate of soda and potash affect it in the same manner. Sulphuric acid produces a bright red colour, or dark rose.

Madder Red is separated from madder purple, in consequence of its not being soluble, in a strong solution of alum. It is obtained by boiling madder in a dilute solution of alum, when a reddish-brown precipitate is obtained. This is repeatedly boiled in pure muriatic acid, then well washed with water, and boiled in alcohol. This dissolves madder red, and madder purple. The alcoholic solution is evaporated and allowed to cool, when there is deposited an orange-yellow precipitate; this is repeatedly boiled in a strong solution of alum. So long as the solution becomes coloured, the insoluble portion is madder red. It is a yellowish brown powder, and imparts to cotton impregnated with the aluminous mordant, a dark red colour when in excess; but if the cotton be in excess, a brick-red colour is produced. Caustic potash forms a violet-purple solution; carbonate of soda a red liquid; sulphuric acid a brick-red solution.

Madder orange is obtained from the two former colouring matters by its little solubility in alcohol. It is obtained by macerating madder for twenty-four hours in distilled water, the infusion strained off and allowed to repose for a few hours, the liquor carefully decanted and filtered through paper; the madder orange remains upon the paper; it may be washed with cold water, and afterwards purified by spirits of wine in which it is not soluble. It is a yellow powder; imparts to cotton impregnated with the aluminous mordant a bright orange colour. When in excess, a boiling solution of alum forms with madder-orange an orange-yellow solution; caustic potash a dark rose colour; carbonate of soda, orange colour; sulphuric acid, an orange-yellow colour.

Madder yellow is characterized by its easy solubility in water; it is a yellow gummy mass; communicates to mordanted cotton a pale nankeen colour, but does not of itself form a true dye. Madder which contains much of this is inferior in quality, as the yellow becomes so incorporated with the other colours as to materially deteriorate them, and to require several operations to free the goods from it afterwards. *Madder brown* is a brownish-black dry mass, is of no importance as a dye-stuff, and does not enter into any of the colours dyed by madder; is neither soluble in water nor alcohol.

Besides these five colouring matters, madder contains two acid substances named *Madderic acid* and *Rubiacic acid*, which have no dyeing properties, and therefore are not to be detailed further than to show the intimate knowledge which chemists possess of this agent; so important were any investigations upon madder considered, that the *Société Industrielle de Mulhouse*

for several years offered 2000 francs as a premium for the best analytical investigation of this substance.

It will be observed, in the brief outline of the five colouring matters of madder, that only three of them are of importance to the dyer. It will also be observed, that these three colouring substances have a similarity of action upon mordanted cottons, taken singly; not one of them forms a good dye, but they constitute the elements which together produce the richest and most permanent red that we are in possession of; therefore, speaking practically, it is only necessary here to consider madder as having only two colouring matters, the one dun or yellow, which constitutes the impurity of madder, and which the dyer endeavours to get rid of. This colouring matter does not combine with the cloth alone, but it has a powerful attraction for the other colouring matters, and combines with them when on the cloth, and has to be separated by after processes. The other, a red colouring matter, which includes the madder red, orange, and purple, for they unite with mordanted cotton as one, and are known to the practical dyer as one. This colouring matter is very difficultly soluble in water, has no strong decoction, can be obtained by boiling, which makes it much less useful in the fancy dye-house, not being very applicable in compound colours; indeed, many extensive dyehouses do not rank madder as belonging to their province; and where it is used in a fancy dyehouse, it is generally to give a peculiar tint to light *drabs* and *fawns*, and for dyeing light salmon colour. When deep colours are to be dyed with madder, the goods must be put into the dye-bath along with the madder, such as described under barwood. But madder, in the hands of a skilful dyer, can be made to produce almost any colour by the variation of the mordants, and the colours produced are all characterised by a degree of permanency which no other dyewood possesses; but the operations for obtaining them are generally tedious. Much skill is also requisite for obtaining and applying the proper mordants for madder.

The first step in dyeing full and permanent colours by madder, is clearing the cotton well with alkaline leys, and then in oily liquor in which sheep's dung is macerated; this operation is repeated several times, according to the nature of the colours wanted. Many attempts have been made to substitute different salts for the sheep's dung, and in some cases with considerable success; but the accounts given of these experiments we have always considered a little exaggerated. There appears to be some peculiar influence in the dung to fulfil the purpose intended, that no substitute we have seen tried can equal. After the goods are considered sufficiently prepared by the alternate washings and macerations, they are what is termed in the language of the dyehouse, galled—that is steeped, or wrought for some time in a decoction of galls, or what is now more commonly used, sumac, when they are ready to receive the proper mordant for the colour required. The various mordants used are the acetate of alumina, acetate of iron, or sometimes a mixture of these two for different shades of brown; the chloride of tin, acetate of lead, and, for variety of shade, the ammoniate and acetate of copper. In dyeing with madder by an iron mordant, it is of the utmost importance that the iron be applied in the state of a protosalt. We have already alluded to an easy method of applying the iron salt in this state by adding a piece of clean iron to the liquor sometime previous to using, by which means any persalt is reduced to the state of a protosalt; but it requires great caution and dexterity to preserve it in such a state when applied to the cloth, for such a length of time as from the mordanting to the immersion in the dye-bath. But these treatises being more particularly applicable to fancy colours, we will not enter into details of the colours obtained from madder, as they will be more properly treated of under the head of *fast colours* upon cotton.

II.—ANOTTA, OR ROUCON OF THE FRENCH DYERS.

This substance, which has been referred to several times in the course of these papers, is obtained from a shrub originally a native of South America, and now cultivated in Guiana, St Domingo, and the East Indies. It is termed the *anotta tree*, or *Bixa orellana*. It seldom attains to more than twelve feet in height, the leaves are divided by fibres of a reddish-brown colour, they are four inches long, broad at the base, and tend to a sharp point. The stem has likewise fibres which in Jamaica are converted into serviceable ropes.

"The tree produces oblong bristled pods, somewhat resembling those of a chesnut; these are at first of a beautiful rose-colour, but as they ripen, change to a dark-brown, and bursting open, display a splendid crimson farina or pulp, in which are contained from thirty to forty seeds somewhat resembling raisin stones. As soon as they have arrived at maturity, these pods are gathered, divested of their husks, and bruised. Their pulpy substance, which seems to be the only part which constitutes the dye is then put into a cistern, with just enough water to cover it, and in this situation it remains for seven or eight days, or until the liquor begins to ferment, which sometimes requires as many weeks, according to circumstances. It is then strongly agitated with wooden paddles and beaters, to promote the separation of the pulp from the seeds; this operation is continued until these have no longer any colouring matter adhering to them. The liquor is then passed through a sieve, and afterwards boiled, the colouring matter being thrown to the surface in the form of scum, or otherwise allowed to subside; in either case it is boiled in coppers till reduced to a paste, when it is made up into cakes and dried."*

Another and much preferable mode of extracting the colouring matter from these seeds is, rubbing them one against another under water, so that the mucilaginous and other impure matters contained in the interior of the seeds are not mixed with it. When extracted in this way, the colouring matter is allowed to settle, the water drawn off, and the anotta left to dry. When prepared in this manner it has a fatty feel, and very homogeneous and of a deep red colour, which changes to dark-brown by drying; it has no taste, but generally a disagreeable smell, which is not natural, but owing to stale urine having been added to it, for the purpose of improving its colour and keeping it moist.

Muriatic acid has no action upon anotta; chlorine discolours it; nitric acid completely decomposes it, giving rise to several chemical compounds which have not been investigated. Sulphuric acid poured upon it in the solid, gives it a deep blue colour like indigo, which changes into a dark dirty green, and then to a blackish purple.

Anotta contains two colouring matters; one yellow, the other red. They are very difficultly soluble in water, but easily in alkalis, and are by this means prepared for dyeing. The alkali used is carbonate of soda or potash, but common soft soap does equally well, and for certain light shades upon silk and cotton, is superior. A quantity of anotta is prepared at a time, and kept as a sort of stock liquor; but the practice is bad as it soon becomes stale, and loses a great portion of its dyeing properties; it ought to be used when newly prepared. It is prepared as follows: into a boiler capable of containing from ten to twelve gallons of water, is put 10 lb. weight of anotta, 2 lb. of carbonate of soda, and 2 lb. soft soap, the whole boiled together until the anotta is all dissolved. Cloth put into this solution will be dyed a dark orange, and every tint of shade from an orange to a light cream colour may be dyed by this solution, by merely using it less or more diluted according to the shade required; the cloth requires no previous preparation; but for light shades, the colour is brightened by having a little soap dissolved in the water where they are dyed: in this case the goods are merely wrought in the liquor for a little, wrung out and dried. The addition of acids turns the colours dyed by anotta to a yellowish red, so that by passing a piece of cloth dyed orange with anotta, through a little acid water, it is turned into a scarlet, and so on down to a light salmon colour. But it is to be regretted, that all the colours dyed by anotta are exceedingly fugitive; and although neither acids nor alkalis can completely remove the colours given by this substance from the cloth, yet they are constantly changing and fading by exposure to air and light, and consequently this substance is very little used to produce a dye by itself in a cotton dyehouse, but as an auxiliary, or what dyers term, giving a bottom to colours, as, in the case of scarlet, the cloth is first dyed orange by anotta, and a crimson dyed above it by safflower, which together produces a beautiful scarlet.

It is used in considerable quantity for dyeing silk and woollen the various shades of orange, salmon, nankeen, &c., the objections just referred to, respecting its use for cotton are not so applicable to silk and woollen, probably owing to the superior affinity that animal substances have for dyeing agents, when compared to vegetable substances.

Anotta is eminently fitted for dyeing the shades alluded to

* Ann. de Chem. tom. 47.

above upon goods of a mixed quality, such as Canton crape, Batiste, and all such cloth composed of cotton and silk, cotton and woollen, silk and woollen,—a kind of goods, which require a considerable experience in the art, to be able to produce an equality of shade of every colour upon the different materials.

III.—CATECHUE.

This is a dry extract prepared from the wood of a species of sensitive plant named *acacia catechue*. This substance was long considered as an earth which was found in Japan, and was consequently called *terra Japanica*. Its true character was first pointed out by Mr Kerr, who published a paper, describing the process of obtaining and manufacturing it from the plant. This plant is indigenous to Hindostan, flourishing abundantly in mountainous parts. It grows to about twelve feet in height, and one foot in diameter, and is covered with a thick, rough, brown bark. The extract obtained from the tree is made from a decoction of the wood. As soon as the trees are felled, all the exterior white wood is carefully cut away, the interior or coloured wood is then cut into chips; narrow mouthed unglazed pots are nearly filled with these, and water is added to cover them and reach to the top of the vessel. When this is half evaporated by boiling, the decoction without straining is poured into a shallow earthen vessel, and further reduced two-thirds by boiling. It is then set in a cool place for one day, and afterwards evaporated by the heat of the sun, being stirred several times during that process. When it is reduced to a considerable thickness it is spread upon a mat or cloth, which has been previously covered with the ashes of cow-dung. This mass is divided with a string into quadrangular pieces, which are completely dried by being turned frequently in the sun, and are then fit for sale. It is a brittle, compact solid, of a dark brown or chocolate colour; has no smell, but a very stringent taste; is soluble in water; contains a great amount of tannin and a peculiar acid which has been named catechuic acid; it is the reaction of these with oxygen and other chemical agents that constitutes its dyeing properties. A solution of catechue in water is a beautiful red brown colour, which will enable the reader to follow within his mind the action of the following re-agents with a solution of catechue in water:—

Acids brighten the colours of the solution.
Alkaline substances darken the solution which increases by standing.
Protosalts of iron give an olive-brown precipitate.
Persalts of iron, olive-green with a brownish tint.
Nitrate and sulphate of copper, turn the liquor yellowish brown, giving a precipitate by a short exposure.
Acetate of copper, a deep brown precipitate.
Salts of lead, salmon coloured precipitate.
Tin salts, brownish yellow.
Bichromate of potash, deep red brown precipitate.

These precipitates are all insoluble, and have an attraction for vegetable and animal substances, so that catechue in the hands of the intelligent dyer becomes an agent of extensive application. It is but a few years since this substance was first introduced into the fancy dyehouse, as an agent for dyeing permanent browns upon cotton yarn. Its introduction raised a considerable excitement throughout the trade, but the parties who introduced it had not a long monoply, from their giving the name of the new brown that of *catechue brown;* which at once betrayed their secret, and before long, catechue brown became common throughout the whole trade. But during the experiments to get at the method of dyeing brown, its application to many other colours became known, so that not only browns, but *fawns, drabs, olives*, and *blacks* were all produced by catechue.

When catechue is dissolved in boiling water it has a gummy consistence, so that yarn cannot be dyed in it in this state. The addition of some metallic salt, such as the nitrate or sulphate of copper, sulphate of zinc, chloride of tin, &c. destroys the gummy principle, so that some one of these salts must be added previous to dyeing yarns by catechue. The chemical change which takes place on the addition of these salts is not well understood. The explanation generally given, is, that the salt added oxidises the catechue, producing an insoluble oxide which however is soluble in a solution of catechue not oxidised, so that the salt added only oxidises a part, which remains in solution in the portion not oxidised. We do not think this explanation is correct, because the oxidation of catechue is its conversion into another substance of a darker colour; whereas the addition of a little nitrate of copper, for instance, renders the solution lighter, besides the fixation of the colour upon the yarn depends upon its oxidation, so that the portion oxidised before going upon the goods would neither alter in shade, nor produce a different shade from that it receives in the solution. As an instance of this, if into a solution of catechue in water there be put sulphate of zinc instead of nitrate of copper, a piece of cotton put into this receives a light buff or nankeen colour; if this is now passed through a weak solution of lime, and then exposed to the air, it absorbs oxygen, and in a few hours becomes a dark permanent brown, little inferior to that dyed in the usual way. There is however no doubt that the addition of a metalic salt facilitates the oxidation of the catechue when upon the goods.

To dye brown, the catechue is boiled in water till dissolved. Let the boiling cease, then add a little nitrate of copper, say that a penny-piece is dissolved in two gills of aquafortis, this will do 10 lbs. of catechue. The whole is well mixed and the cotton immersed and allowed to remain in it till the solution becomes cold, generally over night; it is then to be taken out and well wrung and wrought for nearly twenty minutes in a solution of bichromate of potash (chrome) at nearly a boiling heat; it is then washed and finished through a solution of soap, sufficiently strong to stand a lather after the goods come out. This produces a very rich permanent brown, and is already superseding the use of madder for the same colour, being nearly equally permanent and much more easily obtained. The shade is varied according to the proportion of the ingredients used, so that a rich vautcrine or a dark chocolate may be obtained with equal facility.

We have now gone over the principal vegetable dyeing agents which are used in the dyeing of cotton. There are no doubt many others used in the art of calico printing, and also in dyeing silk and woollen, but we have all along confined ourselves to what is termed the fancy dyehouse, and here the mineral kingdom has in many instances superseded the vegetable; so that we will have to devote a few papers to substances in which the chemical principles of the art will be much more easily developed, as the nature of the substances and their re-action with other mineral bodies have been more thoroughly studied and explained than the vegetable bodies.

THE EQUILIBRIUM OF FRAMEWORK.

Article II.

ARITHMETICAL ILLUSTRATIONS.

The present article may be profitably devoted to an application of the principles laid down in our last, with a more particular explanation of the mode of arriving at some of the formulas there given.

I. We stated that in fig. 1, page 262, making W = the whole weight of the rafter and its load, and H = the horizontal force exerted at C, then

$$\frac{W}{H} = 2 \tan BCA; \text{ and that}$$

$$H = \tfrac{1}{2} W \cot BCA = \tfrac{1}{2} W \frac{AC}{BA}$$

This will appear if we examine into the conditions of equilibrium of the inclined rafter, B C, which may be viewed as resting on a vertical surface, A B, at the ridge, its pressure at that point being equally and oppositely balanced by the pressure of the rafter, B D. At the base, C, the tie-beam must be calculated to sustain an oblique pressure, and for this purpose the rafter is inserted in a notch made in the beam at C. As the resistance

offered by the ideal surface A B must be perpendicular to itself, the horizontal line B M will represent its direction. Again, as the whole weight of the rafter may be supposed concentrated in the middle of its length, or at the point V, it will act in the vertical line M V H. It will be observed then that the two forces, namely, the horizontal pressure at B, and the vertical force at V, meet at the point M. Now, our object must be to complete the triangle of forces, two sides of which are already determined by the lines M H, M B, and thereby we shall obtain the triangle of equilibrium.* The third side must pass through the point C, as being the only remaining point of resistance, and also through the point M, since in this point the forces at B and V are conceived to meet. If we join C M, therefore, the triangle of equilibrium O M H is formed, in which C M and M H are two of the active forces, and C H is parallel and equal to the third force B M; M C is then the resulting strain upon the point C, and it is equivalent to a vertical force equal to the weight, and a horizontal force H C equal to the pressure at B.

Let us now express the horizontal force in terms of the span and height of the rafters. In the triangles B O A and V C H,

$$BA : AC :: VH : HC$$

$$\text{therefore } \frac{HC}{VH} = \frac{AC}{BA}, \text{ and } HC = VH \frac{AC}{BA}$$

Now $HC = H$, and $VH = \frac{1}{2} MH = \frac{1}{2} W$, therefore by substitution $H = \frac{1}{2} W \frac{AC}{BA}$, which is one of the values of H already given.

From this expression we may find the horizontal pressure at the foot of each rafter. For example, let there be a roof of 20 feet span, and 6 feet in height, furnished with rafters of Scotch fir, of which the scantlings are 7 by $2\frac{1}{2}$ inches, covered with slating which weighs $\frac{1}{2}$ ton per 100 superficial feet. To find, in the first place, the value of W, which is equal to the sum of the weights of one rafter, and the quantity of slating borne by it, we must ascertain the length B C of the rafter, and the width between the centres of two contiguous rafters. The latter being found by observation to be 18 inches, the former, if it be not given, must be found from the span and the height. In the right angled triangle B A C, $BA^2 + AC^2 = BC^2$, therefore $BC = \sqrt{BA^2 + AC^2} = \sqrt{10^2 + 6^2} = \sqrt{136}$, or 11·7 feet. To find the weight of the rafter, we know that one cubic foot of Scotch fir weighs 33 lbs., and that 8 feet run of the given scantling, $7 \times 2\frac{1}{2}$, is equal to one cubic foot; then $11{\cdot}7 = 8 \times 1{\cdot}46$, and, consequently, $33 \times 1{\cdot}46 = 48$ lbs. for the weight of one rafter. Again, $11{\cdot}7 \times 1{\cdot}5 = 17{\cdot}5$ square feet, is the area of roofing borne by each rafter, of which the weight will be $17{\cdot}5 \times \frac{10}{100}$ cwt. or 11·2 lbs. $= 196$ lbs. Then $196 + 48 = 244$ lbs. is the total weight W operating at the point V, the middle of the length of each rafter. Now,

$$H = \frac{1}{2} W \frac{AC}{AB} = 122 \frac{10}{6} = 203{\cdot}3 \text{ lbs.}$$

We find, therefore, that the horizontal thrust at the foot of each rafter is 203 lbs. fully.

Thus far, the investigation has been conducted by operating upon lineal dimensions alone. The introduction of the angles and their functions, constitutes an important step in the inquiry, by which, in many cases, it may be greatly facilitated. Viewing the preceding question trigonometrically, the value of H may be found from the given weight W and the angle B C A. In the triangle V C H, let $a =$ the angle at C, then

$$\text{Rad} : \tan a :: CH : HV, \text{ or as } H : \tfrac{1}{2} W,$$

therefore, $\frac{1}{2} \frac{W}{H} = \tan a$, and $\frac{W}{H} = 2 \tan a$, which is the expression with which we set out. From this, we have $H = \frac{1}{2} W \frac{1}{\tan a}$; but $\frac{1}{\tan a} = \cot a = \frac{AC}{BA}$, therefore we have finally $H = \frac{1}{2} W \cot a = \frac{1}{2} W \frac{AC}{BA}$. This last value, it will be observed, is just that to which we formerly arrived.

To apply in practice the equation $H = \frac{1}{2} W \cot a$, for finding the value of H, the values of W and the angle a must be given. Let $W = 244$ lbs., the same as the value found for W in the last example, and let the angle $a = 30^{\circ}{\cdot}51'$. Then

$$\begin{aligned} \text{Log } \cot a &= 0{\cdot}223755 \\ \text{Log } 122 &= 2{\cdot}086360 \\ \hline \text{Log } 204{\cdot}2 &= 2{\cdot}310115 \end{aligned}$$

from which we have 204·2 lbs. for the value of H, or the horizontal thrust. This value is nearly the same as that found in terms of the weight, the height, and the span of the rafters, which implies that the angle at the base is also the same in both instances. To show this, we may calculate that angle from the two sides C B, A B of the triangle, by the following proportion:—

$$BC : BA :: R : \sin C, \text{ or in numbers}$$

$$11{\cdot}7 : 6 :: 1 : \frac{6}{11{\cdot}7} = 5{\cdot}1282 = \sin 30^{\circ}{\cdot}51' =$$

angle C.

The object of the next formula, given in last article, is to determine the direct thrust in the direction of the rafter, and it may be thus expressed:—

$$T = \frac{W}{\sin 2a}$$

or substituting for W the elements of which it is composed, the formula stands as there given,

$$T = \frac{w\,s\,d}{\sin 2\,a}.$$

Recurring to our old example, we have $w = \frac{244}{17{\cdot}5} = 14$ lbs., $s = 10$ feet, $d = 1{\cdot}5$ feet, $\sin 2\,a = \sin 61^{\circ}{\cdot}42' = {\cdot}88048$; then $T = \frac{14 \times 10 \times 1{\cdot}5}{{\cdot}88048} = 238{\cdot}5$ lbs., which is the direct thrust in the direction of the rafter.

In short, we have

$MH = W = 244$ lbs., the whole weight upon each rafter;
$HC = H = 203{\cdot}3$ lbs., the horizontal strain upon each rafter;
$VC = T = 238{\cdot}5$ lbs., the direct strain upon each rafter.

II. The next proposition requiring exemplification, is that illustrated by fig. 4, page 263. The amount of strain which comes upon the oblique tie-beam A D, relatively to the strains which have just been treated of, will be best exemplified by recurring to the data already laid down. The equation for the tensile force on the tie A D, representing it by F,

$$\text{is } F = \tfrac{1}{4} W \frac{AC}{BN}.$$

Here $W = 244$, $AC = 20$, and assume $BN = 3$ feet, then

$$F = 61 \frac{20}{3} = 406{\cdot}6 \text{ lbs.}$$

The value of F here found shows how much greater the strain upon an oblique tie may be than that upon the horizontal tie, and even than the original force which creates it.

III. A horizontal piece B D C, fig. 5, page 263, being fixed at B to the upright B A, which is supposed to be fixed to a wall, sustained by a diagonal strut A D, and loaded at C by a weight W, to find the action of the weight W upon the individual parts of the frame. Following the investigation there offered, we find that in the first place, the upward strain at B caused directly by the weight is $W \frac{l'}{l}$. This will appear on considering that B D C is a straight line acted upon by three forces at the points B, D, C, originated by the weight; in other words, that B D C is a lever of the first kind, in which D is the fulcrum, C the point

* The doctrine of triangles of forces has been already explained in our first volume, page 297, under the head of "Mechanics."

where the power is applied, and B the point at which the resistance is offered; the beam being then held down by fixing to the upright A B. In this view, making R = the resistance at B, we shall have

B D : D C : : W : R = W $\frac{DC}{DB}$ or W $\frac{l'}{l}$, which is the first expression given. Now according to the principles of three parallel forces in equilibrium, the pressure upon the fulcrum D is equal to the sum of the two forces at B and C, that is, to W + W $\frac{l'}{l}$, or as W is the same as W $\frac{l}{l}$, the vertical pressure on D = W $\frac{l+l'}{l}$, which is the second expression given.

As this pressure on the point D acts vertically, we have yet to find how it acts upon the strut A D which lies obliquely. This will be at once found by resolving it into two forces, one operating in the direction D A, and the other acting horizontally at the point A. The triangle B D A furnishes the solution at once, for if the vertical force be represented by B A, it is equivalent to D A in the direction of the strut, and D B horizontally at the foot of it; the former is a compressive force to be resisted by A D, and the latter must be counteracted by an equal tensile strain upon D B. To express these strains by means of the angle a as in last article, if in the triangle B A D, A D be the radius, then A B is the cosine of the angle a, that is,

$$\cos a : R : : AB : AD,$$

and as the strain A B = W $\frac{l+l'}{l}$, $\cos a$: R : : W $\frac{l+l'}{l}$: A D the direct strain upon the strut, consequently

$$\text{the strain } AD = W\,\frac{l+l'}{l\cos a}.$$

In the next place, to express the force, B D, in the same manner, A B being the radius, B D is the tangent to the angle, a, and 1 : tan a : : B A : B D; or W $\frac{l+l'}{l}$, being put for B A as before, the horizontal strain B D = W $\frac{l+l'}{l}$ tan a.

Let the weight W = 250 lbs., l = 24 inches, l' = 12 inches, and A B = 32 inches. Then W $\frac{l'}{l} = 250\,\frac{12}{24}$ = 125 lbs. for the strain upon the point B. The quantity W $\frac{l+l'}{l} = 250\,\frac{36}{24} = 250 \times \frac{3}{2}$ = 375 lbs. for the vertical pressure at the point D, which is the sum of 250 and 125.

As the direct strain on the strut D A is to the vertical strain in the ratio of A D to A B, to find the former, the length of A D must be found from A B and B D; these three sides forming a right angled triangle, A D = $\sqrt{AB^2 + BD^2} = \sqrt{1024 + 576} = 40$ inches.

Then A B : A D : : the vertical strain : the direct strain,
or 32 : 40 : : 375 : 469 lbs. nearly of strain in the direction D A.

To find the same strain from the formula W $\frac{l+l'}{l\cos a}$, the value of cos a must be had from the sides A D, A B of the triangle A B D, thus,

A D : A B : : R : cos $a = \frac{AB}{AD} = \frac{32}{40}$ = ·8; then W $\frac{l+l'}{l\cos a} = 250 \times \frac{36}{24 \times \cdot 8}$ = 469 lbs. nearly, as before.

Lastly, to find the tension on the part, B D, from the formula W $\frac{l+l'}{l}$ tan a; tan a, in the first place, is equal to $\frac{BD}{AB} = \frac{24}{32}$ = ·75, and W $\frac{l+l'}{l}$ tan $a = 250\,\frac{36}{24} \times \cdot 75$ = 280 lbs. fully for the tension on B D.

Again, the construction of the expression for the limit of effort on a superficial unit of the transverse section of the piece D C, when its section is rectangular, depends upon the propositions that the capability of the beam B C to resist the lateral strain of the weight at the point D is measured directly by its breadth and the square of its depth, and by its length inversely, and that the power of resisting the tensile strain upon the part B D is measured by the breadth and the depth simply; or, symbolically, these powers are measured by the expressions $\frac{b\,d^2}{l'}$, and $b\,d$. If then R = the lateral strain upon a superficial unit of the section of the beam at the point D,

W = R $\frac{b\,d^2}{l'}$, and R = W $\frac{l'}{b\,d^2}$.

In like manner, the strain upon the sectional unit of the part B D = $\frac{W}{b\,d}\,\frac{(l+l)}{l}$ tan a. Taking the sum of these strains equal to R′, we have

$$R' = W\left(\frac{1}{b\,d}\cdot\frac{(l+l')}{l}\tan a + \frac{l'}{b\,d^2}\right)$$

$$= W\left(\frac{d}{b\,d^2}\cdot\frac{(l+l')}{l}\tan a + \frac{l'}{b\,d^2}\right)$$

$$= \frac{W}{b\,d^2}\left(\frac{d\,(l+l')}{l}\tan a + l'\right)$$

When W is the weight which, when applied, is just sufficient to cause rupture, R′ is said to be the *coefficient of tenacity or of rupture*, as it represents the weight which, applied on a unit of surface of a given material, will cause rupture.

The principles embraced in the preceding propositions, express most of the conditions which we meet with in practice; but there are numerous modifications of them required to suit the variety of circumstances which the mechanic is called upon to consider. These circumstances are also frequently complicated, especially in the dynamical action of machinery; in other words, the strain upon a part is not always constantly in one and the same direction, and is not uncommonly transferred from one bearing point to another. In consequence of this continual change of condition, a corresponding modification of the sustaining action of the parts must be contemplated and provided for accordingly.

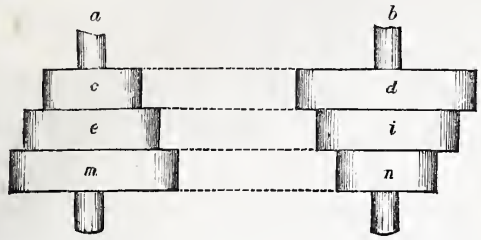
ON LATHE SPEED-PULLEYS.

ARTICLE I.

WHEN motion is communicated from one shaft to another, it is often necessary to give an angular velocity to the driven shaft, different from that which belongs to the driving shaft. When the communication is to be accomplished by means of pulleys and bands, the change of speed is effected by proportioning the pulleys inversely to the velocities of the shafts—that is, the diameter of the pulley on the driver is to that of the pulley on the driven, as the velocity of the driven is to that of the driver. Moreover, it is frequently necessary to have at command the means of accomplishing a *series* of changes of velocity. For this purpose, what is required is a series of pairs of pulleys, calculated to produce the given series of velocities. The common turning-lathe is an obvious case of the application of such changes of motion; and the use of these changes arises from the practice of turning objects of various diameters in the same lathe, and the consequent necessity of producing at the point of the cutting tool, as nearly as is practically convenient, the same tangential velocity of motion of the object to be turned. The systems of pulleys upon the driving and the driven shafts, are each cast in one piece, and from the same pattern, and they are so

opposed to one another when in their places, that the smallest pulley or "speed" of the one corresponds to the largest speed of the other. For example, in fig. 1, a and b are two parallel

Fig. 1.

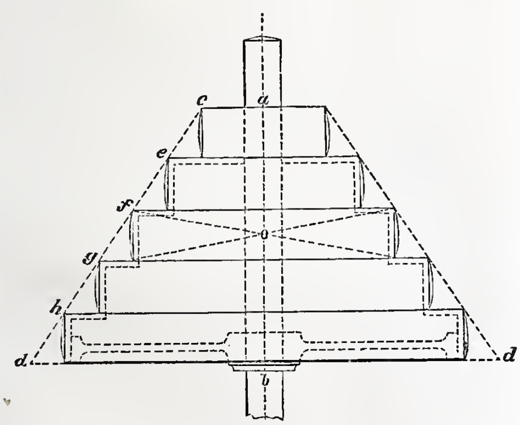


shafts, from one of which, a, the motion is to be communicated to the other b, by two systems of pulleys or "cones," as they are usually termed, which are inversely opposite one another. In this case there are three speeds on each cone; and it is evident, that if the band be passed over the speeds c, d, the rotatory motion of the shaft b will be reduced at the same rate that the diameter of d is larger than c; and that, on the contrary, if the band be passed over the speeds $m\ n$, the motion of b will he increased at the same rate that m is larger than n. Lastly, if the hand pass over the middle speeds e, i, the motion of the shaft b will be equal to that of a, as these speeds are of equal diameter.

Let, then, the shaft a make 20 turns a minute, and the speeds c, e, and m, respectively, 5, 7, and 9 inches diameter, the speeds of the other cone n, i, and d, being also 5, 7, and 9 inches of diameter. Then, from the first pair of speeds c, d, the velocity of the shaft b will be $\frac{9}{5} \times 20 = 36$ turns per minute; from the second pair e, i, it will be $\frac{7}{7} \times 20 = 20$ turns per minute, or the same as a; and from the third pair m, n, it will be $\frac{5}{9} \times 20 = 11\frac{1}{9}$ turns per minute.

For a second example, let us take a pair of cones of 5 speeds, such as are used for a 12-inch lathe. Let fig. 2 represent one

Fig. 2.



of them, the other being an exact counterpart. The following is the usual method of determining the sizes of the speeds of the cone when drawn down for the pattern-maker. Having fixed upon the number of speeds of the cone, their common breadth is next determined; and by taking the product of the breadth by the number of speeds, the extreme length $a\ b$ is also determined, as it must be equal to that product. In the next place, the diameters of the largest and smallest speeds are settled and marked down on the drawing; and two slant lines $c\ d$, being drawn through corresponding corners of these speeds, it is evident that by drawing transverse lines through the points of division meeting the slant lines, the points of intersection e, f, g, h, will indicate the diameters of the intermediate speeds. From this it is evident that there is the same difference of diameters between every two contiguous speeds, and that the sum of the diameters of every pair of pulleys will he the same. The circumferences of the pulleys are usually rounded slightly, to prevent the belt from slipping off. The rounding may be described on each pulley to the radius of the middle pulley f.

For a 12-inch lathe, let the diameters of the largest and smallest speeds h, c, be 20 inches and 6 inches, and let the common breadth of the speeds be $2\frac{1}{2}$ inches. Then $2\frac{1}{2} \times 5 = 12\frac{1}{2}$ inches for the length of the cone $a\ b$; and, as 14 inches is the difference of the extreme diameters, $\frac{14}{4} = 3\frac{1}{2}$ is the difference of two contiguous speeds; consequently, the successive diameters of the speeds c, e, f, g, and h, are in inches,

$$6,\ 9\tfrac{1}{2},\ 13,\ 16\tfrac{1}{2},\ 20;$$

and as the driving cone is of equal dimensions, the corresponding speeds of it are in inches

$$20,\ 16\tfrac{1}{2},\ 13,\ 9\tfrac{1}{2},\ 6.$$

Now, if the revolutions per minute of the driving-shaft be taken at 60, the number of revolutions per minute of the lathe-spindle, supposing the back gear out of contact, will be,

For the first speed, $\frac{6}{20}\,60 = 18$,

For the second speed, $\frac{9\frac{1}{2}}{16\frac{1}{2}}\,60 = 34\frac{1}{2}$,

For the third speed, $\frac{13}{13}\,60 = 60$,

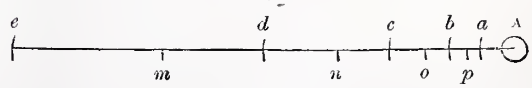
For the fourth speed, $\frac{16\frac{1}{2}}{9\frac{1}{2}}\,60 = 104\frac{1}{4}$,

For the fifth speed, $\frac{20}{6}\,60 = 200$.

Having thus sketched the method of forming cone-pulleys, let us examine the principle upon which the changes of velocity ought to be effected for turning and boring machines.

There is a certain velocity of surface which is the most suitable for the action of cutting tools; and this velocity is independent of the diameter of the objects to be turned, or, in other words, of the distance from the centre at which the tool acts. Consequently, as the *tangential* velocity is constant for all diameters, the *angular* velocity of the spindle ought to be inversely as the diameter, or as the distances of the cutting point from the centre, which is the radius. But in putting up a cone which shall give five different speeds or angular velocities to the spindle, it is obvious that those speeds, though much more convenient than one constant speed, are yet strictly correct for only five different radii, and afford simply an approximation to the proper speed for the intermediate radii. It becomes, therefore, a desirable object so to apportion the succession of the speeds, as to create equal increments of angular velocity, and thereby to afford equally near approximate speeds for the intermediate radii. Let A, fig. 3, be the centre of a lathe provided with five

Fig. 3.



speeds, and A e a horizontal line through that centre, representing the line in which the cutting point acts at various distances from A; let also the distances, A a, A b, A c, A d, A e, be the radii, at the extremities of which, hy means of the five speeds successively, the given constant velocity may be produced. The points, a, b, c, d, e, being then the only points at which the given velocity is exactly attainable, the motion for any intermediate point, m, must be had from the speed for the radius, A e or A d, on either side of it. If the motion be taken from the speed for A d, then the velocity at m is greater than the standard; but if

taken from the speed for $A\,c$, it must be less. There is obviously, therefore, some medium point m, at which the resulting velocities would differ equally from the standard, whether produced by the speed for c, or by the speed for d; being as much less than the standard in the former case, as it would be greater in the latter. There are similar medium points n, o, p, in the spaces $d\,c$, $c\,b$, $b\,a$. Now the points a, b, c, d, e, will have the best arrangement along the line $A\,e$, when they are so disposed that the approximate velocities at the medium points m, n, o, p, will all differ by equal amounts from the standard, whether derived from the faster or the slower speeds.

When, on the one hand, the motions for the points m, n, &c., are derived from the slower speeds, or those for d, c, &c., respectively, the velocity at d is to the velocity at m as $A\,d$ to $A\,m$, and the velocities at c and n likewise are as $A\,c$ to $A\,n$, and so on; and as by supposition there are equal velocities at m and n, and d and c, it follows that

$$A\,d : A\,m :: A\,c : A\,n,$$

and therefore $\quad A\,d : A\,c :: A\,m : A\,n.$

Similarly, when on the other hand the motions for m, n, &c. are derived from the faster speeds for e, d, &c., the velocities at e and m are as $A\,e$ and $A\,m$, and those at d and n, as $A\,d$, $A\,n$, therefore as before,

$$A\,e : A\,m :: A\,d : A\,n,$$
$$A\,e : A\,d :: A\,m : A\,n.$$

Now we found

$$A\,d : A\,c :: A\,m : A\,n,$$

therefore, by equality of ratios,

$$A\,e : A\,d :: A\,d : A\,c.$$

From this we observe, that the distances $A\,e$, $A\,d$, $A\,c$, are in continual proportion, and this relation extends to the quantities $A\,b$, $A\,a$, also.

It appears, therefore, that to fulfil the condition of equal approximate velocities at intermediate distances from the centre, the distances $A\,a$, $A\,b$, $A\,c$, $A\,d$, $A\,e$, must form a geometrical progression. And as all these radii move at one common tangential velocity, their angular velocities, or the corresponding numbers of turns of the spindle per minute, should be inversely as their lengths; and, consequently, also the different rotatory speeds of the spindle ought to be in geometrical proportion.

It would require a lengthened process of calculation to show that the speeds obtained from ordinary cone-pullies do not follow this law. Suffice it to offer one example on this point. Suppose a pair of cones of seven pullies; the smallest diameters are 6 inches, and the largest 24 inches. Then the corresponding diameters are in inches:—

24, 21, 18, 15, 12, 9, 6, for the driven cone,
6, 9, 12, 15, 18, 21, 24, for the driving cone.

The quotients arising from these, and expressing the relative velocities are

$$\cdot25,\ \cdot428,\ \cdot6,\ 1,\ 1\cdot5,\ 2\cdot\dot{3},\ 4$$

The ratios of these terms are expressed by

$$\frac{\cdot25}{\cdot428},\ \frac{\cdot428}{\cdot\dot{6}},\ \frac{\cdot\dot{6}}{1},\ \frac{1}{1\cdot5},\ \frac{1\cdot5}{2\cdot\dot{3}},\ \frac{2\cdot\dot{3}}{4},$$

$$\text{or } \frac{1}{1\cdot7},\ \frac{1}{1\cdot55},\ \frac{1}{1\cdot5},\ \frac{1}{1\cdot5},\ \frac{1}{1\cdot55},\ \frac{1}{1\cdot7}.$$

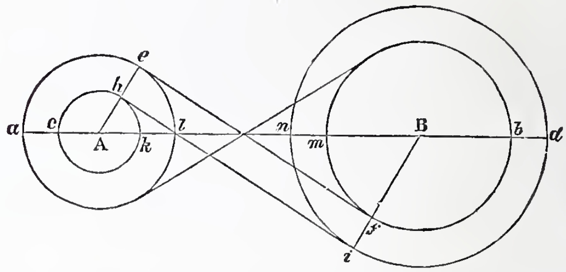
Now, for a series of quantities in geometrical proportion, there is a common ratio for all the terms, whereas it is obvious from this example, that the ratios of the speeds vary; in short, they are equal at the extremes, and diminish towards the middle.

The objection just pointed out has reference to cones driven either by open or cross belts; but there exists another objection to cone-pulleys as they are ordinarily made, of a different nature from the preceding, though the objection is confined to those wrought with open bands. It is the inequality of tension experienced by the band or belt on being shifted from one pair of pulleys to another. The tension, of course, is equal for speeds equidistant from the extremes, as then the diameters of the pulleys are the same; but in other cases generally this does not hold. The only exception is that of a pair of equal cones having only two pullies each. It is true, that frequently the error is covered by the elasticity of the belt, and this is the more easily accomplished the greater the distance of the centres of the cones from each other; nevertheless, it is sometimes desirable to have a nearer approach to exactness for open bands than the common methods of construction will give.

When the band is crossed, the principle of construction by making the sums of the diameters of all the pairs of pullies equal to one another is absolutely correct, so far as tension upon the belt is concerned, as may be shown by means of the following figure.

Let A, B, represent the centres of two shafts upon which two cones are fixed, working together by a cross belt. Suppose a,

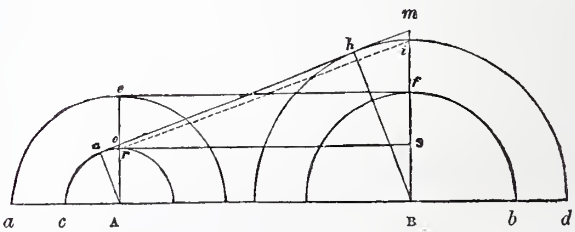
Fig. 4.



b, one pair of pullies working together, and c, d, another pair. Then $a\,e\,f\,b$, and $c\,h\,i\,d$, are the half lengths of belt for the two pairs. Draw the radii $A\,h\,e$, $B\,f\,i$, to the points where the belt leaves the pullies. Now $A\,h + B\,i = A\,e + B\,f$, therefore $h\,e = f\,i$, and the figure $h\,e\,f\,i$ is a rectangle, so that $h\,i = e\,f$. Again, as $A\,h + B\,I = A\,e + B\,f$, the semicircumferences $a\,e\,l + b\,f\,m = c\,h\,k + d\,i\,n$; and as $a\,e$ and $B\,i$ are parallel, the portions of the semicircumferences cut off by these lines must be similar, and therefore $a\,e + b\,f = c\,h + d\,i$, consequently the half length of belt $a\,e\,f\,b =$ the half length $c\,h\,i\,d$. This proves that one cross belt being used upon a pair of ordinary cones, it will sustain equal tension upon them at different speeds, in so far at least as that its length will remain unaltered.

To show how unequal tension is brought about in open bands, let A, B, fig. 5, be the centres of two shafts upon which two cones

Fig. 5.



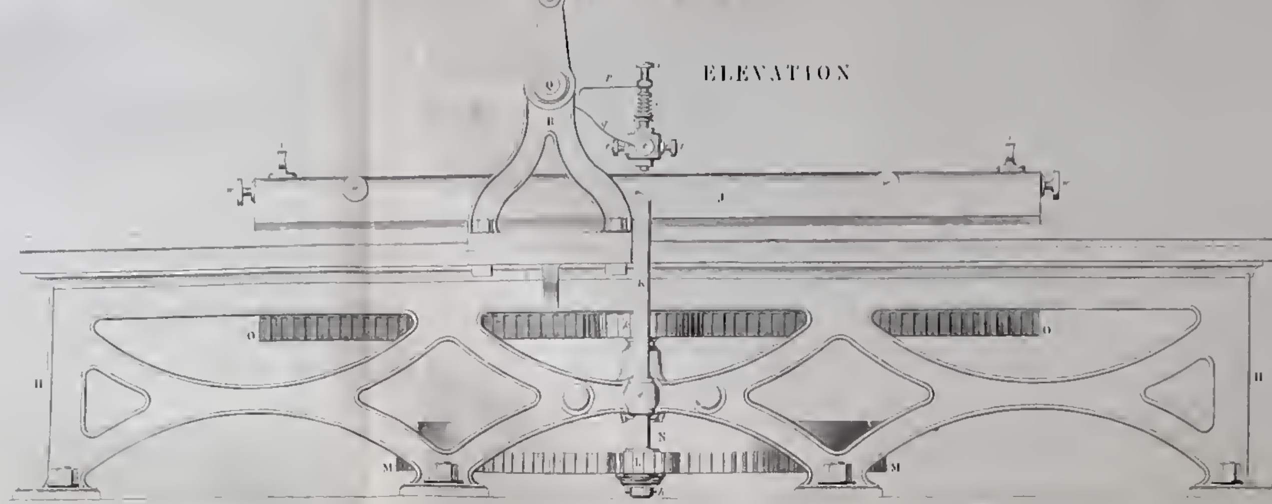
are fixed, working together with an open belt. Suppose a, b, to be two pullies of equal diameter, and c, d, two others of which c is as much less than a or b as d is greater. Draw the tangents $e\,f$, $n\,h\,m$; then $a\,e\,f\,b$ is the half length of belt for the equal pullies, and $c\,n\,h\,i\,d$, is the same for the unequal pullies. Upon $A\,B$, erect the perpendiculars $A\,e$, $B\,i$, meeting the circumferences of the pulleys at e, r, i, f. Draw also $A\,n$, $B\,h$, to the tangent $n\,h$, meeting it at the touching points; join $r\,i$, and make $r\,s$ parallel to $e\,f$. In most practical cases, the angle $h\,B\,i$, or $n\,A\,o$ is so small comparatively, that the tangent $n\,o$ is sensibly equal to the arc $n\,r$, and in like manner $h\,m$ is sensibly equal to $h\,i$.

Again, $o\,m$ is nearly parallel to $r\,i$, therefore these two lines also are practically equal. Accordingly, substituting the lengths $n\,r$ and $r\,i$ for the parts of the belt $n\,o$, $o\,h$, $h\,i$, we shall have for the approximate half length of belt $c\,r + r\,i + i\,d$, or the sum of the one-fourth parts of the circumferences of the pulleys, and the straight line joining them. Now, as $B\,i - B\,f = B\,f - B\,s$ or $A\,e - A\,r$, we have $B\,i + A\,r = 2\,B\,f$, and also the quarter rounds $d\,i + c\,r = 2\,b\,f$ or $b\,f + a\,e$; therefore subtracting

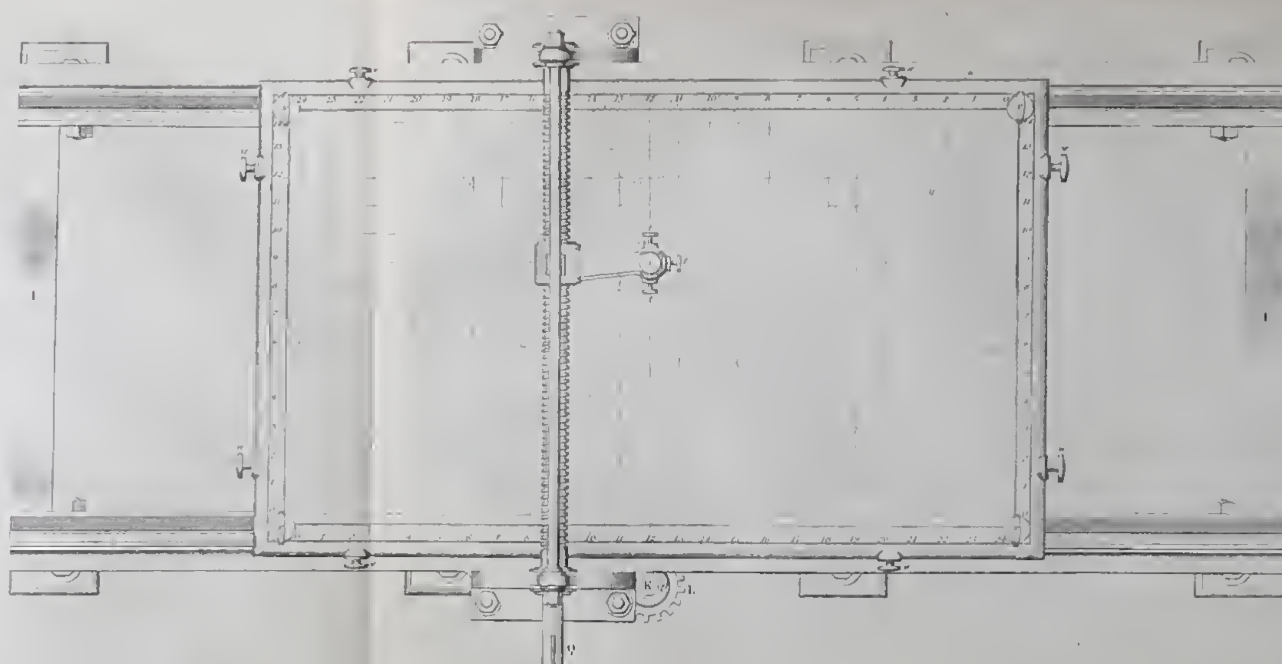
DESIGN OF A TIDE GUAGE.

BY W. M. BUCHANAN.

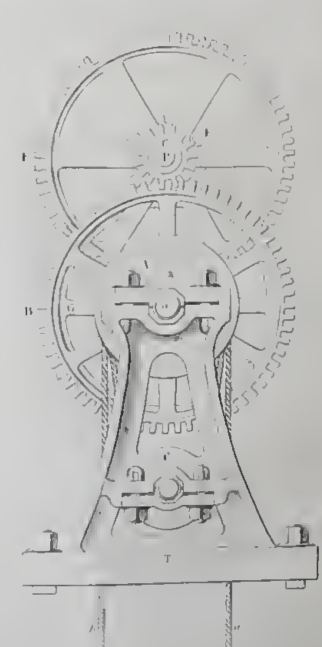
ELEVATION



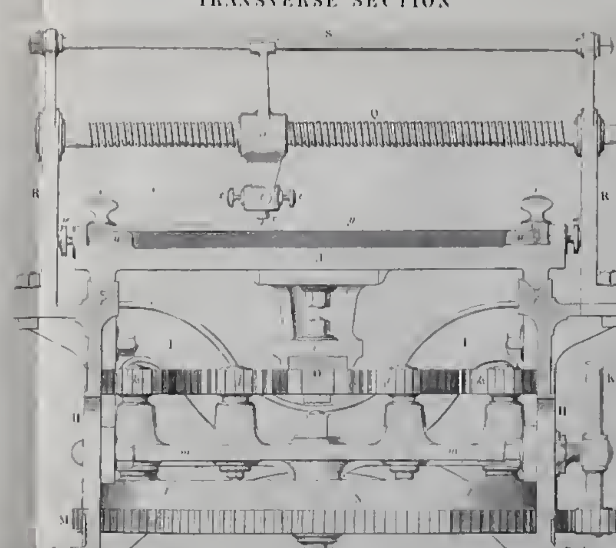
PLAN



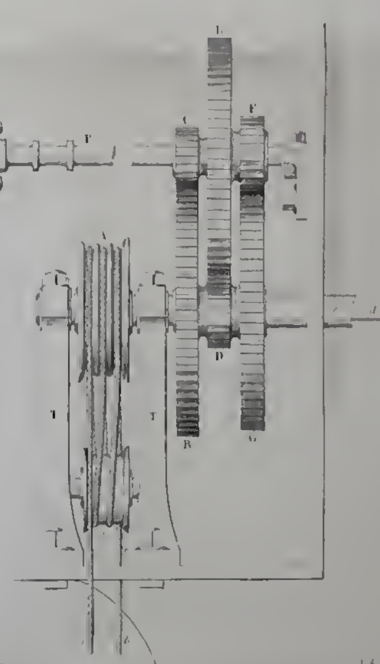
END VIEW OF GEARING



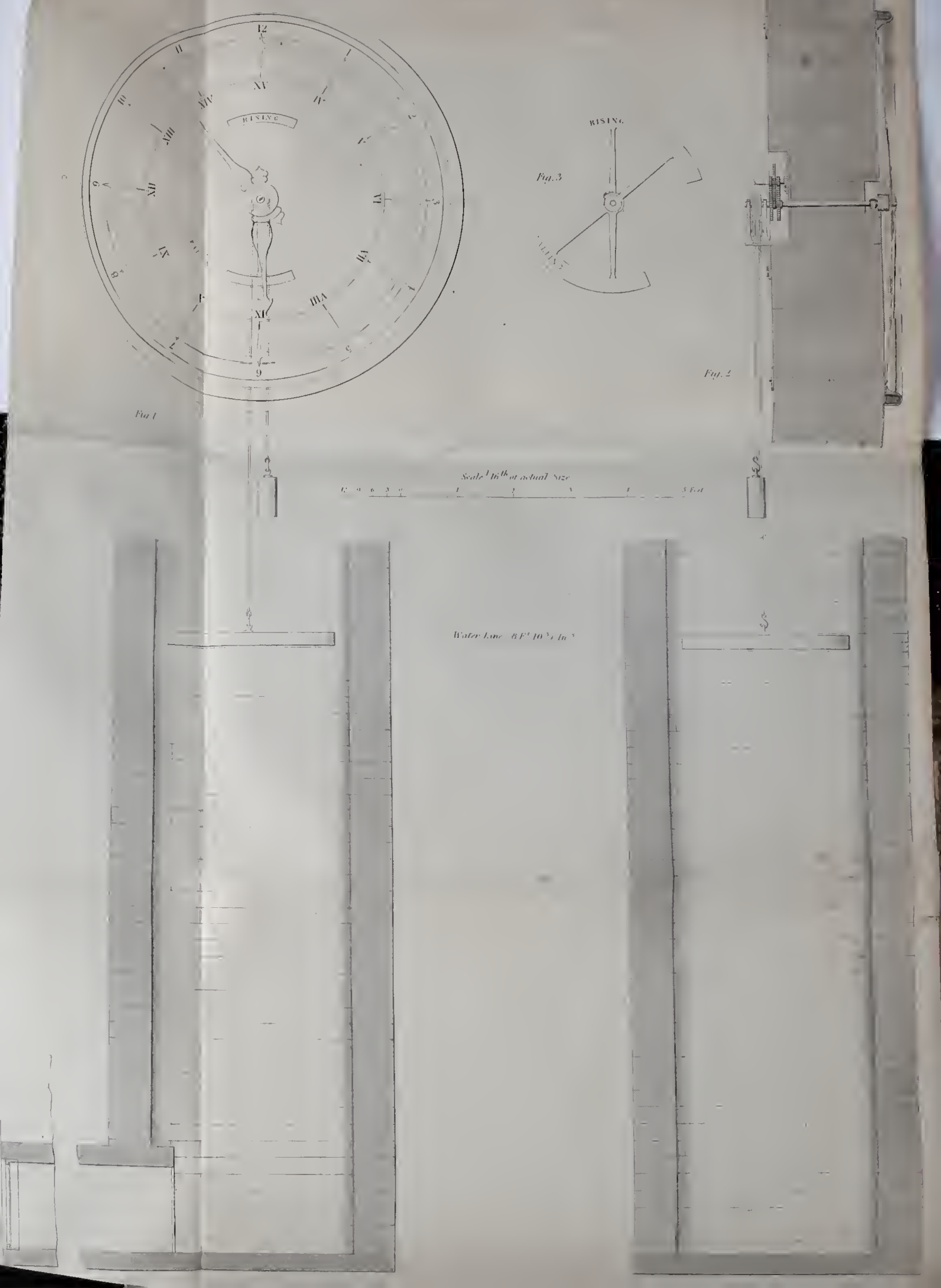
TRANSVERSE SECTION



ELEVATION OF GEARING



DESIGN OF A TIDE GUAGE BY W. M. BUCHANAN



these equal parts from the two half-lengths of belt, the main difference of length must be between the remainders $e\,f$ and $r\,i$, or $r\,s$ and $r\,i$. As $r\,i = \sqrt{r\,s^2 + s\,i^2}$, the difference $= \sqrt{r\,s^2 + s\,i^2} - r\,s$. This quantity evidently becomes greater as the distance A B becomes less, and at considerable distances it will be much less felt, aided too as it is by the greater elasticity afforded by increased distance.

There are then two objections to lathe cone-pulleys of the ordinary construction. First, that the series of angular velocities imparted to the shaft of the driven cone do not progress in the manner most advantageous for practical purposes; this objection applies to cones wrought with either open or cross belts. Secondly, that the absolute diameters of the pulleys are such that the belt is unequally strained when shifted upon different pairs; this objection applies only to cones driven by open belts.

Having thus discussed the nature of the cone pulleys now in use, the next object is to lay down a mode of construction which shall provide first, that the successive speeds of the driven shaft be in geometrical proportion; secondly, that the diameters of the pulleys be so regulated that the absolute length of belt required to embrace them may be the same for every pair.

First, as to the method of determining the relative speeds of the driven cone. In any geometrical progression, if $a =$ the first term, $l =$ the last term, $n =$ the number of terms, and $r =$ the common ratio, then

$$\frac{l}{a} = r^{n-1};$$

from which it is obvious, that to find any one of the four quantities, a, l, n, r, the other three must be given. In the case of a series of velocities by cone pullies, the values of a, l, and n, are commonly given, leaving the ratios to be found by construction. From the above formula, therefore, the common ratio of the speeds may be had thus—

$$r = \sqrt[n-1]{\frac{l}{a}}.$$

As n, in general, is comparatively a high number for the index of a root, it will be convenient to take the logarithmic form of this equation, which then becomes

$$\text{Log}\, r = \frac{\log l - \log a}{n - 1} \qquad (1)$$

Having thus found the value of r for the common ratio of the speeds, it is easy to interpolate their values between the first and last of the series, by either of the following series:

$$a,\ a\,r,\ a\,r^2,\ a\,r^3,\ a\,r^4,\ \text{\&c.},$$

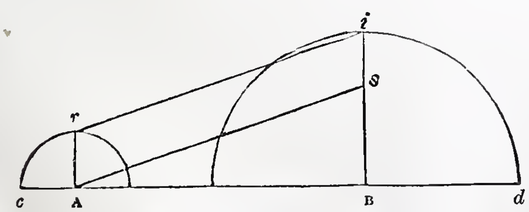
$$l,\ \frac{l}{r},\ \frac{l}{r^2},\ \frac{l}{r^3},\ \frac{l}{r^4},\ \text{\&c.} \qquad (2)$$

Again, to find the absolute diameter of the pulleys which are to produce the speeds formed as above, there must be three given quantities: the ratios of the diameters of the pulleys, which is the inverse of that of the velocities; the distance of the centres of the shafts, aud the length of belt which is to embrace them.

The following is an approximate method of finding the dimensions of the pulleys of the cones.

Let A, B, fig. 6, be the centres of two shafts upon which the

Fig. 6.



pulleys, c, d, are hung; draw A r, B i, perpendicular to A B, join $r\,i$, and draw A s parallel to $r\,i$. Then the half length of belt will be represented by $c\,r\,i\,d = c\,r + \text{A}\,s + i\,d$, and A B is the distance between the centres.

Let $x = c\,r$, the quarter circumference of the small pulley,
$r =$ the ratio of the circumferences of the two pulleys,
$l =$ A B, the distance of the centres,
$\text{L} = c\,r + \text{A}\,s + i\,d$, the half length of belt,
and $\pi = 1{\cdot}5708$;
then $r\,x =$ the quarter circumference of the large pulley.

$$\text{Now A}\,s = \sqrt{\text{A B}^2 + \text{B}\,s^2} = \sqrt{l^2 + \left(\frac{(r-1)\,x}{\pi}\right)^2};$$

$$\text{so that L} = (r+1)\,x + \sqrt{{}^2 + \left(\frac{(r-1)\,x}{\pi}\right)^2}$$

Reducing this equation, we have for the value of x,

$$x = \frac{(r+1)\text{L} + \sqrt{(\cdot 5947(1+r^2) + 2{\cdot}8106r)l^2 + (\cdot 4053(1+r^2) - \cdot 8106r)\text{L}^2}}{\cdot 5947(1+r^2) + 2{\cdot}8106r} \qquad (3)$$

Of the two values of x here given, the less is to be taken for the quarter circumference, and being multiplied by $\frac{2}{\pi}$, or $1{\cdot}273$, it gives the diameter of the small pulley. This again, multiplied by r, gives the diameter of the large pulley.

In our next, there will be given examples of the application of this formula; and there will also be presented a table constructed on a new principle, for facilitating calculations of this nature.

DESIGNS OF A REGISTERING TIDE GUAGE.

By W. M. Buchanan.

(Illustrated by Three Plates.)

The object of this apparatus is twofold—to indicate the depth of water, and to record its indications, at any tidal harbour where it is erected. As a constant indicator of the actual condition of the harbour, it is expected to serve, at least, as a useful convenience, especially in those localities where the state of the tide regulates the entrance and departure of vessels; and by preserving a continuous and trustworthy record of the phenomena affecting it, those constants which depend upon local circumstances will in time become known and available as elementary data in varifications of the tidal theory. A quantitive determination of those constants is besides absolutely necessary for the construction of local tide tables; and it is acknowledged, by all who have devoted attention to this subject, that the modes of observation hitherto adopted to obtain data for the rectification of those tables, afford, at most, only rough approximations in which little confidence can be placed.*

The mode adopted to indicate the harbour depth is by two pointers, which have a common centre of motion in a circular index-plate, similar to the dial of an ordinary turret clock, and conveniently situated for observation. The pointers communicate, by a suitable arrangement of mechanism, with a float placed in a chamber or well, to which the water of the harbour has free access by a proper culvert. They are consequently affected by every change of level to which the float is subjected by the tidal oscillations; and by their positions on the graduated circles of the index-plate or dial, round which they are carried by the angular motion of their axes, represent in all states of the tide, provided they have been correctly adjusted, the depth of the water in the harbour in feet and inches. The mechanism by which the registration is effected, is worked simultaneously by the oscillations of the tide, and by a descending weight in connection with a suitable clock 'scapement. These forces

* Sir J. W. Lubbock, in an excellent tract on the tides in the Companion to the British Almanac, informs the public that the observations are made at the London docks by the watchman, who observes "when the tide begins to fall, or has made its mark; but there is no floating-guage, and the ripple of the water in the docks must prevent accuracy. * * At the St. Katherine Docks the observations are made with about equal precision; the lock-gate is only graduated in feet, the subdivision being left to the eye of the observer. At the East India Dock there is a floating guage, which is placed in a chamber connected with the dock, but, unfortunately, in the way of the capstan, so that it has generally to be removed at the point of high tide." Little has since been done to improve the opportunities for more accurate observations, either at London or elsewhere; and even allowing the observations to be perfectly correct, they are only isolated facts giving the apex but not the character of the tidal curve.

are made to act perpendicularly to each other, and therefore by their motion, describe a curve of which the co-ordinates express the *time* and the depth of water in the harbour referred to a *datum* level. The medium upon which the tidal curve is thus traced may be a plate of engravers' copper when it is desirable to multiply copies of the record, or a sheet of writing paper when the register is to be preserved merely for local examination. Either of these modes of registration may be adopted with the apparatus represented in Plate II, in which the time-movement is rectilineal; but in the modified form depicted in Plate III, in which the time-movement is circular, a medium of paper only can be employed to receive the diagram. In other respects, the machines are identical in principle and mode of action. Both are susceptible of great accuracy, and if properly constructed, would require little attention beyond the renewal of the diagram-surface once a month.

Description of Plate I.

Tide-well or Chamber.—This is sunk to the depth of the lowest low water-mark, and communicates freely with the harbour by a culvert of sufficient size to allow of its being cleaned of sedimentary matters when necessary. The aperture opening to the harbour may be protected against the admission of the grosser debris common in such situations by a proper grating; and in all cases, to prevent the height of the water in the well from being unduly affected by surge and by the commotion produced by the paddles of steam-vessels, the aperture ought to be contracted to a size only *fully* sufficient to allow of the ingress and egress of the volume of water due to the approach and recession of the tide-wave. This can be effected by placing a door upon the aperture of the culvert, with a rectangular opening in it, proportional in area to the volume of water which is required to pass through it in order that the difference of level in the harbour and well may be always a minimum.

A side view of this arrangement is given in fig 1, and a front view is dotted in position in fig 2. The door is hinged to allow of its being opened when it is found necessary to cleanse the culvert; and is kept shut by a species of bar-latch of which many forms might be proposed.

The well is presumed to be circular in plan to correspond with the form of the hollow metal float contained in it. The float is adjusted to the specific gravity of the water and communicates by a water-tight rope-band with the gearing of the indicating apparatus. It is partially sustained by a counter-weight attached to the contrary end of the band and sufficiently heavy to give motion by its descent to the appartus during the rising of the tide when the float is ascending. The force necessary to give motion to the apparatus will likewise determine the minimum preponderance of the float, which in its descent must be capable of reversing the action of the apparatus and of lifting the counter-weight without its depth of immersion being materially altered.

It is admitted that a certain amount of error, both in the indications and in the record, is essential to this arrangement, in consequence of the difference of immersion of the float in its ascent and descent; but this error may be rendered almost inappreciable by employing a float of large horizontal area. Thus, in the drawings the float is assumed to have a diameter of 40 inches, and consequently a horizontal area of 1256·6 square inches; if, therefore, we suppose $31\frac{1}{4}$ lbs, the weight of half a cubic foot of water, to be sufficient to work the apparatus, the entire error will amount to no more than 0·6876 inch of depth; and it may be presumed that the apparatus will be in a very extraordinary state of inefficiency should it require the application of a greater moving force to maintain its action.

Index-Plate or Dial.—The dial has two series of numbers arranged in concentric circles, round which the pointers travel. The external circle is duodecimally divided and marked with the numbers 1 to 12 inclusive; to these divisions the longer of the two pointers refers, and marks by its position the inches and parts of an inch to be added to the number of feet of harbour-depth indicated by the shorter index upon the inner circle of numbers. The division of this circle will depend upon the range of variation between the least and greatest depth of water in the harbour at the ebb and flood tide, and will therefore be different in different situations. The extreme numbers of the series, marking the divisions, express the depths at those limits, and are presumed not to be passed by the pointer in its oscillations. Thus, in the drawing, fig. 1, the range of maximum variation is assumed at 12 feet, the minimum harbour-depth being 3 feet, and the maximum depth 15 feet at highest high water; accordingly the circle is divided into 12 equal parts and marked from IV to XV inclusive. But in situations where the range of variation is greater than 12 feet, it will be necessary to increase the number of divisions and to adjust the mechanism to the diminished unit of interval; and conversely, should the tidal variation be less than 12 feet, the divisions may be increased in magnitude and correspondingly diminished in number. But since it is manifestly not necessary that the shorter pointer should traverse the entire circle of the dial, but only that its motion be so adjusted by the internal mechanism that it shall pass over the interval between two divisions while the longer index makes a complete revolution, equivalent to a variation of 12 inches of harbour-depth, the dial indications may be rendered less liable to misinterpretation near the extremes of high and low water, by laying off upon the circle two more spaces than are comprehended in the ordinary maximum range of variation; and instead of numbering the division at the apex of the circle, to mark it by an arrow-head or other insignificant symbol merely to denote the commencement and termination of the series of numerals. The blank may even be increased with advantage in rivers which are liable to freshes; and under circumstances of that kind, it may even be advisable to change the arrangement by appropriating the external circle, on account of its greater diameter, to the *foot*-divisions and the internal circle to the inches.

It is further of importance, besides showing the actual state of the harbour in reference to the depth of water, that the condition of the tide, in respect to its flowing or ebbing, at the time of ob servation, be also indicated. This is particularly desirable in localities which admit of the state of the harbour being telegraphed to approaching vessels, as at Leith; and in other situations it would at least be a convenience. The object is accomplished by exhibiting the word RISING at an opening in the upper part of the dial during the *flowing*, and the word FALLING at a like opening in the under part of the dial, during the *ebbing* of the tide-wave. These intimations appear at their respective apertures alternately, the word RISING appearing and the word FALLING disappearing immediately on the tide beginning to flow and *vice versa;* and being exhibited in different parts of the dial, they are less liable to be confounded when the distance of observation is too great to distinguish the letters.

The openings in the dial are arcs of the same circle, and the words RISING and FALLING are printed in bold gilded letters upon the lateral faces of two corresponding concentric arcs connected by opposite arms radiating from their common centre, and of sufficient length that when placed upon the hollow axis of the shorter of the two pointers, inside of the dial-plate, the inscribed arcs shall coincide with the openings and screen them. These arcs are limited in their angular movement and are so disposed in relation to the openings that by bringing the inscription on one arc opposite to the opening, and in view, the inscription on the second are shall by the same movement be made to pass behind the dial and disappear, leaving the opening covered by a blank screen.

This reciprocating appendage is shown detached, by fig. 3. The centre being bored to fit freely upon the hollow axis of the shorter index, is provided with a light spring which is made to bear upon the axis to produce friction sufficient to cause it to take the motion of the axis on which it is placed, and bring the arcs opposite to the openings in the dial; and to prevent the arcs being carried past the apertures, stops are fixed on the back of the dial-plate at proper positions to arrest their motion. The axis itself having at all times a motion corresponding to the ascent or descent of the float in the well, answering to the flowing or ebbing of the tide-wave, the same is obviously communicated to the reciprocating arcs within the limits prescribed by the stops, and therefore so long as it continues to move in either direction, the corresponding inscription will remain in view. Thus, in fig. 1, the word RISING is exhibited in the upper opening of the dial, showing that the tide is flowing, and the position of the pointers indicate a depth of water in the harbour of 8 feet $10\frac{3}{4}$ inches. Supposing the apparatus in action, as soon as the depth of water has reached a maximum and begins to decrease, the motion of the pointers will be reversed; and consequently the arcs partaking of the same reversed motion, will intimate the change of condition by the upper arc moving to the left and the lower to the right—the word RISING thereby disappearing behind the dial, and the word FALLING coming into view in the lower aperture.

It is scarcely necessary to remark, that the spring being light, and the friction thereby produced correspondingly small in amount, the resistance thus offered to the motion of the axis upon which the appendage is carried, will not sensibly affect the working of the apparatus. The motion of that axis is moreover very slow; consequently, whatever may be the amount of friction actually induced by the spring, the amount of power consumed by it will be proportionally unimportant in relation to the entire amount required to work the apparatus.

Description of Plate II.

The drawings in this plate exhibit the gearing by which the movement of the float is transmitted to the axis of the dial indices, and likewise one form of the mechanism of the registering part of the apparatus.

Elevation.—This is a side elevation of the registering table and its appendages.

Plan.—This is a plan corresponding, in which the table and the plate of copper fixed upon it to receive the diagram are supposed to be transparent to admit of the arrangement of the under gearing being shown.

Transverse Section.—This is a transverse section through the table on the left of the leading screw in the plane marked by the line 20–4 on the left of the leading screw, Q, in the plan.

Elevation of Gearing.—This shows a side elevation of the arrangement of gearing by which the motion of the float is transmitted simultaneously to the indices and to the leading screw, Q, of the registering machine. The rope-band, marked *a*, ascends from the float, and passing thrice over the triple grooved pulley, A, and twice under the guide pulley, *c*, descends by *b* to the counter-weight. This arrangement is intended to prevent any chance of the band slipping during the working of the machine. According to the relations shown, the pulley, A, is exactly 12 inches round, and therefore makes a revolution for every foot of variation in the vertical position of the float. It is fast on the axis, *d*, which passes through the hollow spindle, *e*, and carries the longer of the two dial indices, viz., that intended to indicate inches, and which will therefore revolve simultaneously with the pulley round the dial. The wheels B and D are also fast upon the same axis, and gear with the pair, C and E, on the axis P of the leading screw. The pinion, C, is fast upon this axis, and will therefore communicate to it an angular velocity which, compared with the velocity of the first axis, *d*, will be inversely as the diameters of the pair, that is as 4 to 1. The pinion, D, being also fast on the first axis, *d*, will communicate an angular velocity to the wheel E, with which it gears, and which is loose on the second axis, P, in the inverse ratio of the diameters, that is, as 1 to 3; but this last is cast with a projecting centre, on which the pinion F is keyed; and this pinion gearing with the wheel G of four times its diameter, and fast upon the hollow spindle *e*, which carries the shorter dial index, communicates to it an angular velocity, which, compared with that of the first axis, *d*, will be in the ratio of 4×3, or 12 to 1. The arc described by the second or unit index upon the dial for every foot of variation in the vertical position of the float will therefore be 30 degrees, or the twelfth part of a revolution.

The relative diameters of these wheels may manifestly be changed at pleasure to suit any given range of tidal variations. For example, were the machine to be constructed for a port at which the maximum variation is 20 feet, the pairs, E, D, and G, F, would be adjusted to give an ultimate ratio of not less than 20 to 1; and it might be deemed advisable, as before intimated, to increase the range to a ratio of 22, or even 24 to 1.

The arrangement depicted is liable to objection on account of the smallness of the diameter of the pulley A. This may be readily obviated by placing the pulley A upon a separate axis, and connecting it with the axis, *d*, by a pair of wheels proportional to the increased diameter of the pulley. And in localities where the tidal variation is small, it might even be advisable to increase the size of the pulley to an extent which would admit of its being placed upon the hollow axis of the unit index, and thereby reduce the train of gearing to four wheels.

Registering Machine.—According to the arrangement of gearing above described, the second axis, P, is presumed to make four revolutions for every foot of rise or fall of the float. But this velocity-ratio will manifestly depend upon the scale on which the tidal variation is intended to be registered; and also upon the pitch of the leading screw, Q, which is coupled at *n* to the axis P. The scale of diagram to which the drawings of the apparatus are adjusted is a twelfth. The pitch of the leading screw, Q, is $\frac{1}{4}$th inch; and having an angular velocity of 4 to 1 of the primary axis *d*, the nut *o*, which carries the tracing point, *x*, will therefore be made to pass over an inch of the surface of the table by one revolution of the pulley A, that is, by a tidal variation of 12 inches. This scale of diagram may manifestly be modified at pleasure by simply modifying the single pair, B, C, of the primary gearing without in any way altering the pitch of the leading screw. Thus, if a scale of $\frac{1}{2}$ inch to the foot of tidal variation were deemed sufficient for the register, the wheels, B, C, instead of a ratio of 4 to 1, would be reduced to the ratio of 2 to 1, and the purpose would be accomplished without in any way disturbing the other parts of the mechanism. Any other scale may obviously be attained in the same manner and with equal facility.

The leading screw, Q, revolves in bearings in the standards, R R, which are bolted upon brackets cast on the side of the table framing, H H, and is connected to the axis, P, by an adjustable coupling, *n*. This coupling consists of two discs with hollow bosses which are keyed upon the adjacent ends of the screw and the driving axis, P, and with circular slots through which jam-pins are passed to hold the discs tightly together face to face. Before fixing the coupling, it is to be observed that the tracing point is immediately over the longitudinal line upon the table corresponding in relative position to the height of water in the harbour. The slots in the discs are intended to allow of adjustment of the screw; and when the coupling is fixed, should it be found that the tracing point does not exactly indicate the condition of the tide, it may be slightly shifted by the adjusting screws, *t t*.

The nut *o* is prevented from revolving with the screw by a forked tail, which slides upon the guide-rod, S, which is fixed parallel to the axis of the screw in the side standards, R R.

The table, J, is supported on the frame, H H, in V-grooves, *f f*, cut in the horizontal ledges of the frame, and is free to move horizontally in a direction perpendicular to the travel of the nut, *o*. This movement is communicated by the spindle, K, which derives its motion from a descending weight regulated in its action by a suitable clock 'scapement. This spindle has a bearing at *g*, and carries a pinion, L, on its lower extremity, which gears with a large spur wheel, M. This wheel is free to revolve on a centre, *h*, projecting beneath the platform, *m m*, and is formed of a piece with an internal half wheel, N, which gears alternately with the pinions, *l l*, on the same axis as the pinions *k k*. These last communicate by the two carrier wheels, *j j*, with the double rack, O, which is fast upon the under side of the moveable table, J.

The object of this arrangement is to obtain an alternate rectilineal motion of the table from the continuous circular motion transferred through the axis K and pinion L to the wheel M. This wheel having thus a uniform circular motion, and carrying with it the internal half wheel N, will bring this last alternately into action with the pinions *l l*. But these pinions being fast on the same axis as the pinions *k k*, their motions will be transferred to the table through the carriers, *j j*; and as the segment can be in gear with only one of the pinions at any time, its motion will be transferred to that side of the rack, and the table will receive a corresponding rectilineal motion. When the wheel, M, has made half a revolution, the segment, N, will begin to act upon the second pinion, *l*, and through this will act upon the contrary side of the rack, O, and thereby reverse the motion of the table.

The wheel, M, is intended to make a complete revolution in 48 hours; accordingly the segment, N, will pass over one of the pinions, *l*, in 24 hours, causing the table to move from one extreme position to the other in that time; and the segment engaging with the pinion, *l*, on the contrary side, the motion will be reversed, and the table will return in the succeeding 24 hours to its normal position.

The motion of the table is thus the measure of the time, as the motion of the nut on the leading screw is the measure of the variation of harbour-depth, and admits of adjustment to any required scale of diagram by simply altering the diameter of the pinion L, on the driving axis, K. According to the scale assumed, an hour of time will be represented on the abscissæ of the tidal curve by a space of 1 inch, and therefore the whole length of the diagram corresponding with the length of the travel of the table between its extreme positions, will be 24 inches. But it is manifestly not necessary that any particular unit of measure be taken to represent an hour; for the motion of the table being uniform, and its gearing so adjusted that it shall move between its two extreme positions in 24 hours, the division of the space travelled over into a corresponding number of equal parts, will each represent 1 hour. And these hour spaces may be subdivided into any desired fractional parts of the hour.

The copperplate to receive the diagram is fixed in a rectangular frame, *u u*, by the four pins, *v v*.... screwed into the corners of the frame. The frame itself is fixed within a ledging which surrounds the table, by the set screws, *w w*... The horizontal surfaces of the sides parallel to the motion of the table, are divided into 24 equal parts marked with the numbers 1, 2,.... 24 on one side, and with the same numbers in an inverse order on the contrary side, answering to the *travel* and *return* of the table by one revolution of the time wheel, M, of 48 hours. The ends of the frame are likewise divided into equal parts corresponding in number to the number of feet of tidal variation in the harbour and in

magnitude to the scale to which the gearing of the machine is adjusted. These unit divisions being marked with any subdivisions which it may be deemed proper to insert, serve as scales for the division of the surface of the copperplate into rectangular spaces in the manner represented in the plan. This division of the plate is intended to be done by hand after it is fixed in the frame, *u u*, but before is has been fixed upon the table, and therefore before the tidal diagram has been traced upon it. In order that the registration may be as complete as possible, it will be of advantage that the machine be provided with two plate frames properly graduated. This will allow of one frame being always unemployed, so that previous to the plate being removed from the table, another may be framed, and ruled, and ready to be inserted the instant the other is withdrawn. The exchange ought also for convenience to be made when the table is near one of its extreme positions. The tracing point being raised slightly by a few turns of the tension screw, *r*, and the set screws, *w w*, being loosened at the end of the table overhanging the end of the bed-frame, H, the plate-frame, *u u*, may be raised from below and withdrawn, and the reserve frame with its plate substituted without in any way disturbing the motions of the machine. No re-adjustment of the machine will be necessary provided the frames be exactly alike, and the set screws be properly fitted on three sides. The frame being dropped into its place, it will only be necessary to tighten the end screws and bring the tracing point again into contact with the plate to re-establish the condition of the machine. There is no risk of derangement of the tidal gearing, and with ordinary care and dexterity the time movement will be little more liable to disturbance.

It may be observed that the machine might, by the addition of a few parts, be rendered capable of effecting the division of the copper surface; but as the plates are intended to receive the diagram of at least 14 days, and generally of a whole lunation, and can be ruled by hand, after they are fixed in the graduated frame, with facility and accuracy, it has been deemed advisable to omit the lining apparatus in this form of the machine, as the advantage to be gained by its application does not seem adequate to the additional complexity introduced into the machine. It is also obvious that by a very slight modification of the frame *u u*, it may be adapted to support a sheet of writing-paper instead of the copper plate, to receive the diagram: but when a medium of that kind is to be employed, the moving table may be replaced by a cylinder as in the form of apparatus to be subsequently described.

Literal References.

A, the driving pulley, over which the rope-band from the float passes.

B, wheel fast on the axis of the pulley A.

C, pinion fast on the second axis P, and engaged with the driver B.

D, pinion also fast on the axis of the driving pulley A.

E, wheel loose on the second axis P, and gearing with the pinion D.

F, pinion also loose on the second axis P, but fast on a boss-centre cast on the wheel E.

G, wheel fast on the hollow axis *e* of the shorter of the two dial indices, and gearing with the pinion F.

H H, cast-iron sides of the frame of the registering apparatus.

I I, end pieces of framing.

J, moveable table resting on the side pieces H H.

K, axis communicating with the time movement.

L, pinion on the lower extremity of the axis K.

M, large spur-wheel engaged with the pinion L.

N, internal segment formed of a piece with the wheel M, and gearing with one of the pinions *l*.

O, double rack attached to the bottom of the moveable table J, and gearing with the carrier wheels *j j*.

P, second axis of the gearing attached by the coupling *n* to

Q, the leading screw of the machine, on which is the travelling nut *o*.

R R, standards supported on the sides of the machine, and carrying the leading screw, and

S, guide to prevent the nut *o* from revolving with the screw.

T T, bracket on which the journals of the axes of the pulley A, and of the guide pulley *c* are carried.

a, rope-band from float—*b*, same band leading to the counter-weight.

c, guide or friction-pulley, by which the rope-band is passed into the grooves of the pulley A.

d, axis of the pulley A, and which carries the longer dial-index.

e, hollow index which carries the shorter dial-index.

f f, V-grooves in the ledges of the frame H H, in which the runners of the moveable table slide.

g, journal of the time-axis K.

j j, carrier wheels which gear with the double rack O, and with the pinions *k k*, fast on the axis of the pinions *l l*.

l l, pinions which gear alternately with the internal segment N.

m m, platform supporting the under gearing of the machine.

n, adjustable coupling connecting the leading screw Q with the axis P.

o nut on the leading screw carrying the tracing point *x*.

p, arm projecting from the nut *o* to receive the adjusting screw *r* of the tracing point *x*,

q, second arm projecting from the nut *o*, and carrying the tracing point and its adjusting appendages.

r, screw by which the tension of the spring *s* is adjusted, and the tracing point *x* made to bear more or less heavily upon the surface of the plate.

t t, *t t* set screws, by which the final adjustment of the tracing point is effected.

u u, rectangular frame on which the copper-plate *y* is fixed by the screws *v v*.

w w, set screws by which the frame *u u* is adjusted on the table.

x, the tracing point, consisting of a diamond spark set in the end of a brass pin, which sliding vertically in a casing made fast by the set pins *u u*, is acted upon and kept in contact with the surface of the copper by the spring *s*, the tension of which is adjustable by the screw *r*.

y, the copper plate placed to receive the diagram traced by the point *x*.

z, tidal line, presumed to have been described by the point *x*, in consequence of the motion of the table from left to right, and of the motion of the point *x* in a perpendicular direction.

PLATE III.—Figs. 1 to 6 inclusive, represent a modification of the tide-registering machine, which may be employed in preference when the diagram is intended to be traced upon paper with a view to local use only. The gearing connecting the machine with the float is in every respect the same as before described, and is therefore not represented. The leading screw, A, receives the same relative motion and the time movement communicated by the wheel M to L on the spindle F, may be derived from a 'scapement in every respect the same as that employed to impel the table of the machine above described. But between the machine and the 'scapement a reversing motion is placed, and so adjusted that the angular motion of the spindle, M, shall be reversed every 24 hours; thereby at the same time reversing the motion of the driving axis, F, and consequently of the cylinder, D, round which the paper to receive the diagram is wound. On each end of this cylinder is fixed a wheel, H, of the same pitch as the wheels, I, which run loose on the axis of the leading screw, and which in turn gear with the wheels, K, on the driving axis F. The cylinder may have any circumference greater than 24 inches (the scale of the diagram being 1 inch to an hour); the circumference also of the carrier wheels, I, must not be less than 24 inches, which is their angular motion in 24 hours; and in moving through that space, in consequence of their being engaged with the wheels H, bring 24 inches of surface of the cylinder under the tracing point D. The wheels, I, having made 24 inches of a revolution, their motion will be reversed by the reversion of the motion of the driving axis. These wheels, I, have each a flange, N, projecting laterally, divided into spaces of an inch, and marked by the numbers 1, 2, 3, . . . 24, cut in relief. These come successively into contact with the surface of the paper on the cylinder and give their impression, thereby recording the horary divisions of the diagram. Any subdivisions of the hours may in like manner be impressed by having them engraved on the circular scales N.

The divisions of the diagram answering to the tidal variations are marked by a series of projecting edges formed on the roller O, which is kept in close contact with the surface of the paper on the main cylinder by two weighted levers on a second axis. This apparatus is shown detached by fig. 6, on a scale of half its proper size. The rod S being accurately divided into spaces of ½ inch, answering to half feet of tidal variation, according to the scale of diagram here supposed; it is then reduced (by turning) between the divisions, leaving edged ridges projecting at the marked distances. Every second edge is afterwards notched to mark the dotted lines corresponding to half feet upon the diagram. The roller is carried on adjustable centres at P P in the arms Q Q, which

are keyed on the second axis, R. On this are also keyed the weighted levers, S, which keep the roller, O, in contact with the surface of the paper covering the main cylinder.

Figs. 4 and 5 show the construction of the main cylinder. It consists of a periphery of thin copper or brass attached at the ends to lateral flanges cast on the wheels, H, and stiffened by two deep edge rings of the same material. The edges of the covering at Z Z stand just sufficiently apart to admit of the ends of the sheet of paper, intended to receive the diagram, to pass freely between them. This sheet is sufficiently long to surround the cylinder and allow the ends to pass between the tension rods, Y Y. These rods are connected by springs, X X, having a slight inward curvature (not properly shown in fig. 5), and are connected by joints to the nuts, W W, on the right and left-handed screws cut on the rod V, which has checked bearings (also incorrectly shown) at U U attached to the axis, T, of the cylinder. By turning the axis, V, so as to separate the nuts, the rods Y Y are drawn tightly together and towards the centre, thereby causing the sheet of paper, the ends being caught between them, to embrace the surface of the cylinder closely. The nuts are prevented from turning round with the screwed rod, V, by tails projecting into slots cut in the main axis, T.

Previous to the application of the paper to receive the diagram, the surface of the cylinder is covered with a sheet of copying paper. That known as Wedgewood's carbonic paper is in every way suited to the purpose; a covering of it would be found to serve for several years without renewal. By this arrangement no pencil is required. The diagram is formed on the surface of the paper in contact with the prepared covering of the cylinder, and is consequently reversed from what it would be if traced by a pencil point upon the external surface of the paper. The best form of tracing point seems to be, after due consideration of the compound motion to which it is subject, a small revolving disc set with a spring socket into the arm C of the nut on the leading screw. This nut is prevented from revolving with the screw by the forked tail, E, which slides along the axis, T, as a guide.

Diagram.—Fig. 7.—This is intended to convey an idea of the diagram formed by the apparatus. The actual scale of the co-ordinates, to which the machines are adjusted, is as before intimated, 1 inch to a foot of tidal variation and an hour of time. The drawing is accordingly half the full size; but where extraordinary accuracy is not required, and especially with the mode of registration by engraving, this reduced scale may be considered sufficiently large. Any part of the tidal curve may be read off upon such a diagram at least to the tenth part of a foot of height, and of an hour in the time, and in very many situations the action of aërial currents will not admit of a closer approximation.

The curves of the tide at Glasgow are roughly traced by hand for eight successive days, according to the time of high water given in Messrs Lumsden's Memorandum Book. The curves, it will be observed, never coincide, and might easily be followed and read off, even if the diagram were continued through a whole lunation. This becomes a matter of importance where the engraving process is resorted to; but when the diagrams are to be taken on paper, it may be desirable to change the sheet every week.

Literal References.

A A, leading screw of the machine. Pitch $\frac{1}{4}$ inch.

B B, bearings of the leading screw.

C, projecting arm from the nut on the leading screw carrying—

D, small revolving disc, by which the diagram is traced.

E, tail from the travelling nut to prevent its revolving with the screw.

F, driving axis, serving also as a guide to the tail E, and carrying the driving wheels K K.

G G, bearings of the main cylinder.

H H, large spur wheels fast on the axis of the main cylinder.

I I, hour wheels, acting as intermediates to the drivers K K, and those on the axis of the cylinder. They run loose on their axis.

K K, driving wheels fast on the axis F.

L and M, meter wheels, which convey the time movement to the axis F.

N N, hour circles attached to the hour wheels I I,

O, division roller, by which the *height-lines* are laid off upon the diagram.

P P, adjustable pivots on which the division roller revolves.

Q Q, arms between which the division roller is carried by the pivots P P.

R, spindle on which the arms Q Q are keyed.

S, weighted levers on the spindle R to keep the division roller in contact with the surface of the cylinder.

T, axis of the main cylinder.

U U, bearings of the screwed rod, V.

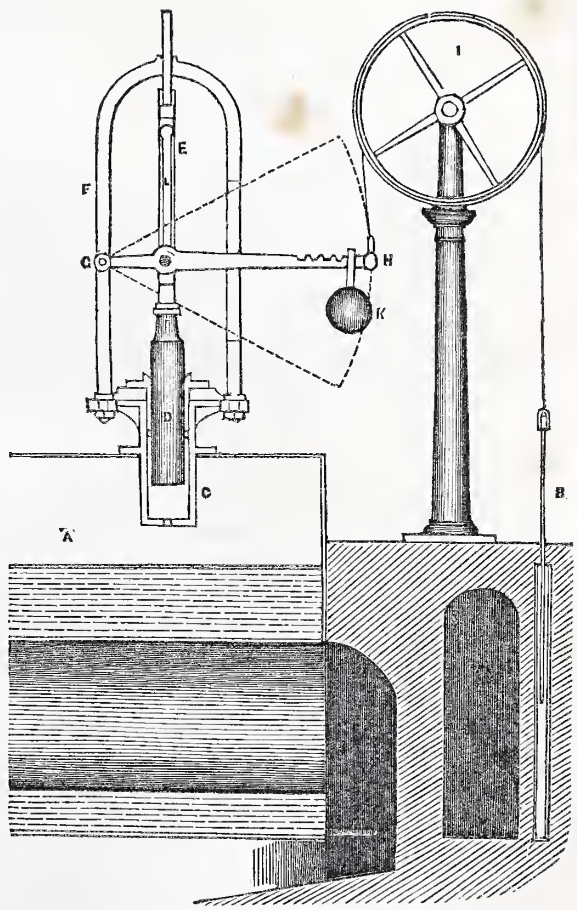
W W, nuts on the right and left handed screws of the rod, V.

X X, four curved springs set obliquely, and jointed to the nuts, W W, and parallel rods, Y Y.

Z Z, flanges along the unjoined edges of the cylinder covered, and between which the ends of the sheet of paper intended to receive the diagram are passed to direct them between the parallel rods, Y Y.

DESIGN OF A SELF-ACTING DAMPER.

The apparatus, of which the annexed is a sketch, is intended for the regulation of the damper of a high-pressure boiler. A, the boiler; B, the damper; C, a cylinder of small dimensions, half inserted into the boiler, and bolted to it; D, a plunger, working steam-tight in the cylinder, through a stuffing-box, and guided in its motion by a grooved rod, E, working in the top of a frame, F, erected upon the cylinder. Through the groove in the rod, E, a



lever, G H, is passed, having its fulcrum at G, and connected at H to the damper by a chain passing over a pulley, I. A counterweight, K, is hung upon the lever to oppose the weight of the damper. The lever is connected to the guide-rod of the plunger by a link, L, so as to partake of its motion vertically.

When the steam becomes too strong, it presses up the plunger, which lifts with it the end, H, of the lever, and, consequently, lowers the damper, thereby checking the draught. *Vice versa*, as the steam diminishes in force, the plunger is pressed down by the unbalanced portion of the weight, K, which operation lifts the damper, and increases the draught.

DREDGE'S SUSPENSION-BRIDGE.*

The bridge, of which a sketch is annexed, was built for the Indian government, and put up across the river Kubbudduk, near Jessou, about fifty miles north of Calcutta. Every part is proportioned, strong enough to resist the action of the heaviest loads, as it has to sustain the heaviest and most trying description of traffic, such as the marching of infantry, the tread of laden elephants, &c.

The design is shown in the accompanying sketch, of which

Fig. 1.

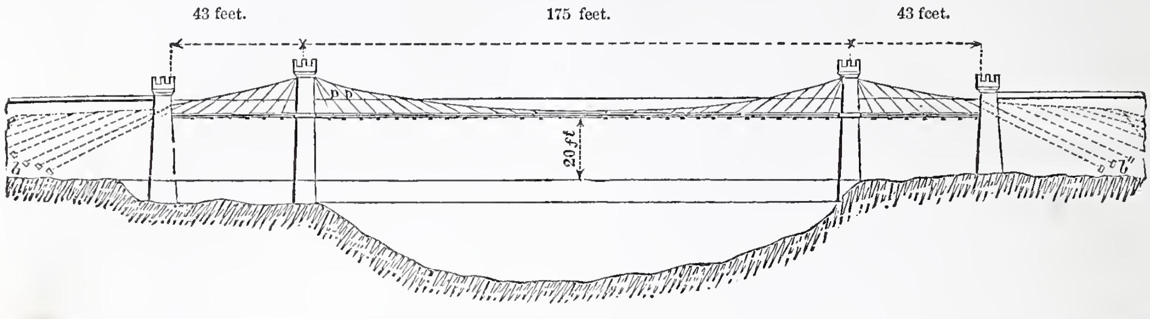


fig. 1 represents an elevation of the bridge. At the flood level the river is 293 feet wide, but at low water it is above 154 feet. The length of the suspended platform is 261 feet, which is divided into three openings, the central one being 175 feet span. The two outside openings are each 43 feet. The road-way of the bridge is 20 feet above high-water mark. The depth of

Fig. 2.

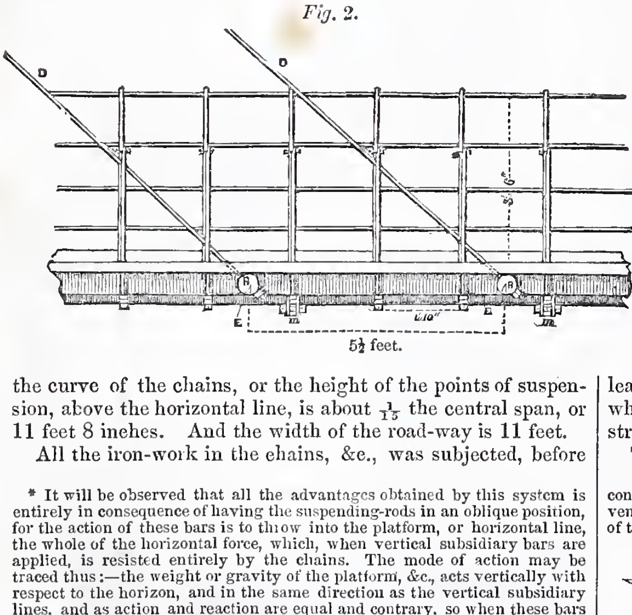
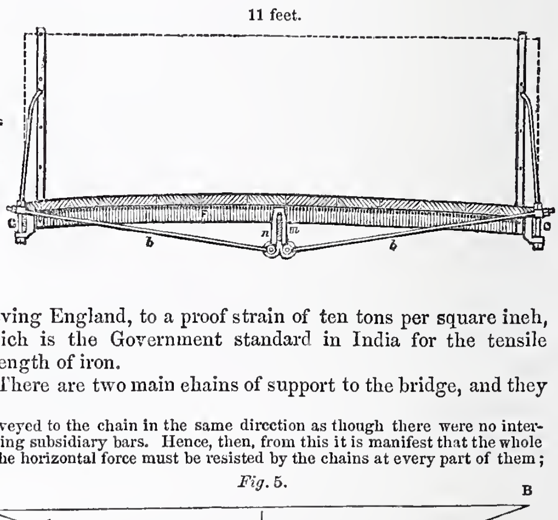


Fig 3.



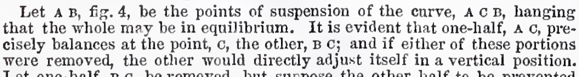
the curve of the chains, or the height of the points of suspension, above the horizontal line, is about $\frac{1}{15}$ the central span, or 11 feet 8 inches. And the width of the road-way is 11 feet.

All the iron-work in the chains, &c., was subjected, before leaving England, to a proof strain of ten tons per square inch, which is the Government standard in India for the tensile strength of iron.

There are two main chains of support to the bridge, and they

* It will be observed that all the advantages obtained by this system is entirely in consequence of having the suspending-rods in an oblique position, for the action of these bars is to throw into the platform, or horizontal line, the whole of the horizontal force, which, when vertical subsidiary bars are applied, is resisted entirely by the chains. The mode of action may be traced thus:—the weight or gravity of the platform, &c., acts vertically with respect to the horizon, and in the same direction as the vertical subsidiary lines, and as action and reaction are equal and contrary, so when these bars are used, the strain or tension in them must be precisely the same as that portion of the weight they respectively support. If weight be sustained in any other position than vertical, it must be by the joint action of at least two forces, the resultant of which is equal to, and in an opposite direction to the weight supported; also, the resultant of the weight, and either one of the forces must be equivalent to and in the direction of the remaining force.

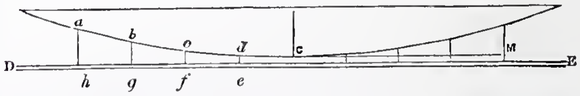
Fig. 4.



Let A B, fig. 4, be the points of suspension of the curve, A C B, hanging that the whole may be in equilibrium. It is evident that one-half, A C, precisely balances at the point, C, the other, B C; and if either of these portions were removed, the other would directly adjust itself in a vertical position. Let one-half, B C, be removed, but suppose the other half to be prevented regaining the vertical position by a force applied at the point, C, in the direction, C M; make, C M, the measure of this force, and it will be the measure of the tension at the point, C, or vertex of the curve, and of the horizontal force above alluded to, and it is a constant quantity acting in that direction in every part of the semi-curve. Take any point, b, and the tension at that point is equal to the resultant of the force, C M, and the weight of that portion of the curve, b C, acting in the direction of gravity, and at the point of suspension, A, it is equal to the resultant of the same force, C M, and the weight of the semi-curve, A C.

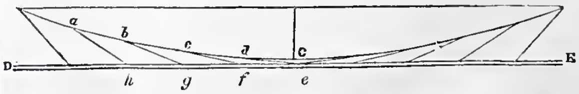
If the platform, D E, be attached to the curve with vertical bars, as in fig. 5, the same effect exhibited above will still be produced, for this reason, viz., that from the lines, a h, b g, &c., acting vertically, there is the same weight conveyed to the chain in the same direction as though there were no intervening subsidiary bars. Hence, then, from this it is manifest that the whole of the horizontal force must be resisted by the chains at every part of them;

Fig. 5.



and that at the centre, the sections of iron, there must be sufficient to overcome the tension caused by it. On the other hand, if we turn to the instance, fig. 6, where the oblique bars, a h, b g, &c., are applied, we shall, by examining their particular mode of action, see that the constant horizontal force does not obtain, nor is there any tension at all existing in the chains at the point, C; and for this reason the whole weight of the platform, D E, must be conveyed to the chains by means of the *oblique* rods connected thereto for that purpose; each of these bars will sustain and convey to the curve its proportion of the weight. Let us instance the one, d e, and trace the effect of it on the system in sustaining that proportion of the weight acting at the point, e. Now the line, d e, is in an oblique direction with the horizon, and different to that in which the weight acts; therefore, in order that it may sustain that

Fig. 6.



weight, it must be acted upon by two forces at the point, e; one of these is the weight, and the other the horizontal force in the direction, D E, consequent upon that weight being supported at the angle, D e d, or otherwise than in a vertical direction. Now, the point, e, is situate in the platform, and, therefore, the horizontal force induced there must be resisted by it, and cannot be carried into, or affect the curve beyond the point d towards C. The action of the other lines may be examined in the same manner; for instance,

are composed of round bars of iron, $\frac{7}{8}$ths of an inch in diameter, in links 6 feet 4 inches long. There are fifteen of these links, and two of the oblique suspending bars resting on the towers, which gives ten inches sectional area at each point of suspension. From this the chains decrease, by reducing one link at each joint, so that at the centre of the bridge the section of the chains is but equal to a single bar, $\frac{7}{8}''$ in diameter, or ·601″ sectional area. The suspending bars that attach the road-way to the chains are inclined to the horizon in the manner shown in the elevation, fig. 1. They are $\frac{3}{4}$ths of an inch in diameter, and connected to the road-way, as represented by fig. 2, which is a section of the elevation to a larger scale, where G is one of the main beams of the road-way; D D, oblique suspending bars; E E, circular castings bolted to the beam, G, through which the oblique bars pass, and are by this means connected to the road-way. The distance on the horizontal line between every two points of the connection of the oblique bars, D D, is 5 feet 6 inches.

The road-way is formed of, first, two wrought-iron beams, G G, 5 inches deep by $\frac{5}{8}$ths of an inch thick, to which the oblique suspending bars, as above described, are connected. There is one of these beams on each side of the bridge, and extending the whole length of it. The transverse joists are also of wrought-iron, and fixed at right angles to the beams, G G. They go across underneath, and immediately support the planking of the road-way (which is laid longitudinally with the bridge). These joists are placed 1 foot 10 inches apart. They are 11 feet long, which is equal to the width of the road-way, and are 4 inches deep by $\frac{3}{8}$ths of an inch thick. They are curved slightly upwards, which raises the road in the centre about 2 inches. Fig. 3 is a transverse section of the platform; G G, the main side-beams; F, transverse joists; *b b*, truss-rods, supporting every third joist in the centre by the cast-box, or prop, *m*. In order that all the joists throughout the bridge may have the advantage of this truss, there is a beam, *n*, seen in transverse section, fig. 3, and in longitudinal section, fig. 2, passing through the cast-box, *m*, and parallel to the beams, G G; and by this means each of the intervening joists between those that have the truss-rods applied are supported, and consequently, the lengths of all are reduced from 11 feet between the support to 5 feet 6 inches, and the transverse strength and stiffness of the road-way proportionably increased.

The plan of the railing is seen on a large scale, figs. 2 and 3. It is made entirely of wrought-iron, having standards attached to every joist.

The rear-chains of the bridge are constructed precisely as those over the stream, and the oblique rods are carried from it in the same manner, but instead of being attached to a beam similar to G, are taken below the abutments, and firmly fixed in the blocks of stone, *b b*, &c., which constitute the moorings of the chains.

The quantity of iron used is,

	Tons.	cwt.	qr.	lbs.
In the chains, &c., . . .	9	18	0	5
Roadway, . . .	10	7	3	14
Railing, ...	3	9	1	7
Cast-iron, . . .	2	19	2	14
	26	14	3	12

the tension in *c f* is induced by the action of the weight supported at *f*, and the horizontal force generated by that weight, being resisted in an angle of less than 90°, and as the point, *f*, to which the various forces tend, is in the horizontal line, the horizontal force acting there must be resisted by the platform, and cannot produce any effect in the chain beyond the point, *c*, and so on for the remaining bars, *b g*, *a h*, the weight suspended at the points, *g* and *h*, generating no horizontal force in the chains beyond the points, *b* and *a*, the truth of which may be demonstrated in the same way as the bars just instanced. Therefore it follows, that though with the use of the vertical suspending-rods, the variation of tension, and, of course, the required proportionate variations of sections of iron in the chain, is so very inconsiderable as to be hardly worth notice; yet, when the oblique rods are applied, the tension in the chain is reduced rapidly from the base to the centre of the bridge, and, of course, in the same proportion may the section of iron in them vary also.

From this it appears that the action of the oblique rods is to throw into the platform or horizontal line the whole of the horizontal force, when it is as essentially serviceable in the support of the bridge as the chains themselves; for the heavy trussing which is usually used in the platform of suspension bridges on the old plan, is intended to keep the platform rigid; in short, to compensate for the horizontal force that should exist there, and which is beautifully maintained in that line by the action of the oblique rods. —*Mining Journal.*

The estimated strength of the bridge for transit purposes is 120 tons on the central span, and 30 tons on each of the outside openings; that is, 180 tons, as the weight which the bridge will sustain at one time, and to which the iron has been proved —so that the platform, when equally loaded, will bear about 153 lbs. per square foot of surface.

AGRICULTURE.

CHAPTER VI.

INSPECTING, TAKING, AND STOCKING A FARM.

Agricultural customs vary in the British islands very much according to locality. To attempt to describe them all far exceeds our space. The following is a summary of them as far as regards the present subjects, as they exist in Northumberland, the Lothians, &c.:—

In these districts farms are uniformly let upon leases, these leases being, upon arable farms, almost invariably for either nineteen or twenty-one years. They have doubtless arisen from the fact that, until comparatively recently, the land was neither enclosed nor drained, and no tenant would undertake either of these operations, unless he was sure of retaining his farm for a sufficiently long period as to reap the benefit of his expenditure and trouble. The attachment of the farmer to these long leases on farms that are enclosed and drained is probably excessive. A long lease is not without its drawback. If the tenant finds his farm not profitable, still he is saddled with it; if he dies, his family, who are, perhaps, quite ignorant of agriculture, must still keep it on, until the expiration of the lease; the restrictions imposed in many Scottish leases are far more degrading than holding at will; that the Scottish farmer is any more independent of his landlord in politics than an English one who has a farm held at will is doubtful; it is a notorious fact that in countries where long leases prevail, the farms change hands oftener than where such are not the case; and, lastly, farms held on lease are usually higher rented. Still the system of leases has worked well, and brought about the most productive farming.

In the parts of the country to which we refer, when a lease is coming to a close, it is usual to try to privately arrange with the occupying tenant. If this is not done, or if the landlord and tenant cannot agree, it is common to advertise the farm in the newspapers, and to fix a day for deciding upon the new tenant. In the meantime, those who wish it, send in written offers, stating what amount of rent they are willing to pay.

Any one intending to offer for a farm inspects it, receives the opinions of his friends regarding it, and then calculates what crops of grain, &c., he can procure, what amount of stock he will annually have to dispose of, and what quantity of wool he will have to sell, then the expenses of labouring the farm, the amount of capital he will require, and then making up his mind what profit he will be content with, he makes his offer.

If the offer is accepted, the lease has to be drawn out, and the various covenants that have been agreed upon inserted. Properly speaking, the only conditions that ought to be imposed upon the tenant are, that he pay the rent, and that during the last three or four years of his lease, he do not over-crop the ground. Generally speaking, however, there are a great many more than these.

In the first place, the landlord usually reserves to himself the game. This not only produces heartburnings, but, if pheasants are much preserved, prevents the farmer from destroying most destructive vermin, and compels him to pay rent without being able to sell all his crop. In the next place all sorts of restrictions are put upon the cropping. These, upon almost adjoining estates, may be diametrically opposed to one another, and all tend to retard agricultural improvement. No shoemaker would undertake to make shoes after a particularly detailed manner for twenty-one years to come, and it is not easy to see why a farmer should act differently. Practically, these restrictions are very little attended to. Kaim hens, driving coals, other acts of servitude, &c., are remains of feudalism, and are, in the present state of things, improper and practically found injurious.

Subletting is generally prohibited to the tenant, and this seems not unreasonable.

The periods that rents are paid at is fixed in the lease. These vary, but the most convenient to a tenant are the terms of Candlemas and Lammas. In England, the usual rent-days are Ladyday and Michaelmas. Sometimes the rent is a fixed sum of money, sometimes as much money as a certain fixed quantity of wheat, barley, and oats would sell for, and sometimes partly one and partly the other.

Entry is sometimes at Martinmas, but the most common plan is, for the farmer to have entry to the house, buildings, and grass at Whitsunday, and to the remainder at the separation of the crop. Sometimes the straw and dung are steelbow, as they are called, *i.e.*, the straw and dung of the previous year are given to the incoming-tenant for nothing, on condition that he leave those of the last year of his lease to his successor. This custom is found a particularly convenient one.

Although restrictions with regard to cropping are improper, the tenant should always lay down a regular plan or system of rotation. It is not that a farmer who properly understands his business may not grow any kind of crop as often as he likes, but in ordinarily situated localities, it is found most economical to grow such a number as will never allow either horses or men to be idle. Sometimes very complicated systems of rotation are followed, but the simpler they are the better. Modifications of the same system constitute the four-course, the five-course, and the six-course rotations, which we will describe. We should premise, that in the districts we are in this chapter alluding to, there is no such thing as permanent pasture, save in exceptional cases, to be found. In many parts of England there is a very erroneous and opposite practice prevalent.

We will take a four-course shift.

The first year is called the fallow year, not that the land is ever fallowed, but that the crops now taken occupy the same position in the rotation as the fallow used formerly to do. The fallow division of the farmer is divided amongst peas and beans, potatoes, turnips, and a few vetches. This fallow division receives a good dunging, *i.e.*, every acre receives from twelve to twenty tons of farmyard manure, and four or five cwts. of guano, or five or six cwts. of bones, dissolved usually in sulphuric acid. The turnips are consumed on the farm, unless manure can be bought, in which case it is immaterial whether they are so consumed or sold.

The second year, the land that had been fallow is under wheat and barley, among which rye-grass and clover seeds are sown. The beans, peas, and potatoes are invariably followed by autumn-sown wheat, and formerly it was the custom for all the turnips to be followed by barley, but now a portion of what was turnips is often succeeded by spring-sown wheat. Some farmers apply no manure to the wheat and barley, but top-dressing them is now frequently done, and invariably with profit; and it is found that the best top-dressing for wheat and barley is guano, to the extent of about two cwts. per acre, sown in May.

The third year, the rye-grass and clover that were sown amongst the corn are the crop. A portion is made into hay, and the rest either cut and carried to the animals, or the animals are allowed to pasture upon part of it. At the end of autumn, this is ploughed up. Sometimes no manure is applied to the grass and clover, but of late it has become customary to topdress it; and it is found in practice, that the best top-dressing is a mixture, in about equal parts, of nitrate of soda and sulphate of ammonia. The proper quantity per acre of this mixture is considered to be about two cwts.

The fourth year, the land that was grass is oats, and these sometimes receive a top-dressing of twelve cwts. of guano. The year after is the fallow year, or first of this four-course rotation.

The fifth and sixth course merely differ from this in allowing the grass land to remain as grass for two or three years.

Having taken the farm, signed the lease, formed his plan, and taken possession, the farmer has next to provide himself with stock, animals to labour his farm, and implements. The rotative proportion of stock and cattle varies so much, according to locality and caprice, that it is not easy to state it. The horses and implements upon a farm of 250 acres, and managed upon the four-course rotation, would be as follows. We should observe that, in the districts to which we confine ourselves, every ploughman has charge of one plough, and one pair of horses, that pull it, and two carts, each of which is drawn by one of his horses. The law in Scotland permits one man to drive two carts on the high-road:—

Horses, ...	10	Corn-sowing machine,	1
Ploughs, ...	5	Turnip do., ...	1
Carts, ...	10	Bean do., ...	1
Harness, ...	10	Thrashing-mill, . .	1
Small plough, . . .	1	Horse-hoe, ...	1
Harrows, ...	5	Hay-chopper, . . .	1
Carriage for do., . .	1	Turnip-shears, . . .	1
Swing-trees, . . .	5	Cake-breaker, . . .	1
Feering-poles, . . .	5	Corn-bruiser, . . .	1
Grass-seed harrow, .	1	Water-cart, . . .	1
Finlayson's grubber, .	1	Weighing-machine, .	1
Two-horse roller, . .	1	Corn sacks, ...	40
Presser-roller, . . .	1		

To these must be added a great number of small articles, as wheelbarrows, scythes, rakes, graips, and so forth. Besides the money necessary for the purchase of these, the farmer must provide the sums requisite for his seeds, his servants' wages for some time, and his own personal and household expenditure, until his returns begin to come in. His rent is never sought from him until he has had time to sell his first crop, or, at any rate, part of it.

The beginning farmer has likewise to hire his servants. Agricultural servants, as grieves, ploughmen, &c., are usually engaged by the year or half-year. Hiring-markets are held, and are considered very objectionable. Any one wanting servants had far better make it known by advertisement in the papers, or otherwise, and he is sure to get plenty of applicants, regarding whose qualifications and character he can make due inquiry. Without good servants, the management of a farm becomes most disagreeable labour, and no pains should be spared to secure them. Field labourers are usually people in the neighbourhood, employed by the day.

Another but minor detail that the farmer has to attend to, is to make arrangements with the smith and wright. It is the custom in the parts of the country to which we confine our observations, to make as many contracts as possible with these tradespeople, and not to have things done by the job, such being generally overcharged. The smith usually undertakes to shoe two horses, uphold the plough-irons, and all the malleable iron of farm implements, for £2. 10s. a-year. That is to say, the farmer pays the smith £2. 10s. per annum for every plough that he keeps. In like manner does the wright undertake to mend and paint the wood-work connected with the implements, for the same sum per plough or pair of horses. The saddler, too, contracts to keep the harness in order, and for each pair of horses receives about a pound, or from that to thirty shillings.

DOMESTIC MEDICINE.

CHAPTER VIII.

ON THE CAUSES, THE PREVENTION, AND THE DOMESTIC TREATMENT OF THE DISEASES OF INFANCY.—CONTINUED.

In addition to what was said in last chapter on the subject of *teething*, we may now state, generally, the chief origin of the diseases incident to this period of infant life. The very shades of the thousands of victims who have fallen a prey to mismanagement at this period of their existence, and whose deaths are erroneously attributed to teething, call aloud to every medical man to raise his voice and expose a system of infant treatment, based upon the most foolish and cruel prejudices, and utterly at variance with common sense and sound physiology.

If the formidable symptoms and fatal diseases, which

occur during the cutting of the small milk teeth, are solely to be attributed to the process of dentition. why is the cutting of the second, or permanent teeth, accomplished with so little trouble, and why is even the cutting of the large double teeth in infants so seldom attended with dangerous symptoms? The period of life in which the first set, or milk teeth, make their appearance, is one of peculiar susceptibility in the infant frame. At that age, the growth of the body, and particularly of the brain and intestines, proceeds at a much more rapid rate than it does during any future period of its existence, of the same duration; and, for the accomplishment of this rapid growth, the vital energy must be unusually active, and the blood must be sent in large quantities, and with great vigour, to the growing organ. In no eondition of an organ is inflammation more apt to arise than when its vital energies are acting with the greatest vigour: when the liver, for instance, is stimulated into great activity by the effects of temperature in a warm climate, and when the female breast is called into active exercise by the secretion of milk, inflammation and subsequent disease are very apt to oceur in both these organs upon the supervention of an exciting cause, which, under different eircumstances, would not have produced the least bad effect. The brain, intestines, and other bodily organs of the infant, are precisely in this excited and highly susceptibile state during the first epoch of its existence, from the excessive activity of their growth. Undue determinations of blood to any of these organs will, therefore, be produced by very slight causes; and if the health be impaired by bad management or indigestible food, or if the blood has become too rich, and the body too full by the digestion of overabundant or stimulating food, the wonder ought not to be that the irritation of teething should cause inflammation of the brain, water in the head, convulsions, inflammation of the bowels, &c., but, on account of the general mismanagement to which infants are subjected, it is surprising that so many survive this period.

Teething is a natural process; and, although cases do occasionally occur of difficult dentition under the most favourable circumstances, it will invariably be found that the healthier the child—neither too weak, and impoverished by a deficient supply of its natural food, nor too strong, and too full of blood by food of an over-stimulating quality—the easier will this process be accomplished.

If, on the other hand, the child's health be impaired by mismanagement; if its mother be labouring under any disease, or have any physical or moral disqualification for suckling her infant; if it be stuffed with improper and indigestible food, or dozed with deleterious medicine; if it be subjected to living in bad air, to uncleanliness, &c.; or if, in addition to an abundant supply of rich and nutritious milk, it be fed with other food during the first six or seven months of its existence, so as to produce an over-full habit of body, then we must expect the irritation of teething to produce symptoms the most formidable, and diseases which, unless checked in the very outset, all the powers of medicine are inadequate to subdue.

Weaning and Artificial Feeding.—No precise time can be fixed as the proper age at which *weaning* ought invariably to take place. Its propriety will depend much more on the health and strength of the mother and child, and on the length to which dentition has advanced, than on the age. It may be given, however, as a general rule, that a child ought not to be weaned, at the earliest, sooner than the end of the *seventh*, nor suckled longer than the end of the *fifteenth* month. But between these two extreme points there is a golden mean, not fixed and determined, but equally well marked and easily recognised.

It may be laid down as a general rule, therefore, which ought invariably to hold good, that, unless under very peculiar circumstances, weaning should not be commenced till the child has cut *four*, nor delayed after it has cut *eight* teeth. When this has been accomplished, in obedience to the visible dictates of nature, as exhibited in the means being supplied to the child of supporting an independent existence, the connecting link between it and the mother, so far as wet-nursing is concerned, ought to be severed; and not more for *its* sake than for *her* future health and safety, weaning ought immediately to take place.

Circumstances will occur, however, in which the above general rule must be departed from, and these may arise in conneetion with either the mother or the child.

If, notwithstanding the use of every means to keep her up, the strength of the mother's constitution prove unable to endure, without hazard, the debilitating effect of the constant drain of milk from her system; if her health begin to exhibit symptoms of giving way, such as the occurrence of loss of appetite, weakness and feebleness of body, wasting of flesh, dimness of vision; and, above all, if the supply of milk get much diminished in quantity—the breasts remaining quite empty till the child commences to suck—and if she begin to be affected with night perspirations, and to be slightly annoyed with a short dry cough—under these circumstances, the suckling of the child by the mother, whatever its age or condition, must be instantly stopped, and it must be either provided with a milk nurse, if possible, or failing that, it must be supported by artificial food.

If, on the other hand, the child have a very delicate and weakly constitution; if it be affected with any disease, such as measles, hooping-cough, or be otherwise unwell, the period of weaning ought to be postponed till the child get stronger, or recover its health, so as to be capable of submitting to the change of food without material detriment.

The appearance of teeth marks a new era in infant life. Before this period, the extreme sensibility of the mucous membrane, or internal lining of the stomach and bowels, is only adapted to the mild and unirritating nature of the mother's milk,—a fluid which has been provided by nature as amply sufficient for its healthy nourishment and growth; any other food, of whatever kind, will prove irritating, and more or less injurious in proportion as its quality is different from human milk. But by the time the teeth begin to appear, the stomach, intestines, and all the other organs have acquired more strength, and less susceptibility, having gradually become adapted to food of a different kind, and of a more varied and stimulating character.

It is not so difficult, therefore, to provide a child with the proper food when the time has arrived at which it ought to be weaned, as to devise a fitting substitute for the mother's milk, when from peculiar circumstances a child must be weaned before the legitimate time, since nothing can be found which is exactly similar to, or can adequately compensate for, its natural support—the milk of a healthy woman.

As we have already stated, such circumstances will happen, from the health of the mother giving way—from her being attacked with disease of the breasts—from her labouring under any constitutional disease, such as scrofula, consumption, epilepsy, or any other illness—from her want of the natural secretion of milk—from the nipples being obliterated by the pressure of tight stays—from an extremely sensitive and excitable temperament—and from, under any of these circumstances, inability to procure a wet-nurse as a proper substitute. In such a case, the food nearest in quality to that of a healthy woman's milk must be supplied to the child; and it must be given in such quantity and in such a manner as will be the nearest approximation to the mode in which it derives its supply from the breast. Even after every effort to imitate the natural process of feeding a child by administering its food of a proper quality, in a proper quantity, and in a proper mode, most spoon-fed children die; and those few who survive the period of infancy, rarely acquire such a strength of constitution as to carry them through any severe illness which may attack them in after life.

With regard, then, to the *quality* of the food employed in artificial feeding, it must be entirely *fluid*. The undiluted milk of animals, such as the ass, or cow, is too rich, containing too much oil and cheesy matter, to constitute a proper substitute for human milk; it ought, therefore, to be diluted with warm water, with the addition of a little sugar, in the proportion of one table spoonful of water to two or three of

milk. This, however, often disagrees with children, producing acid fermentation in the stomach and bowels, and passing through them in the form of firm curds; it is, therefore, found by experienced nurses that a much better mixture is that of a table spoonful of well-boiled gruel, made from barley, the flour of oatmeal, sago, arrow root, or ground rice, and two table spoonfuls of fresh-drawn cow's milk, with the addition of a little white sugar. This ought to be freshly prepared every time the child is fed, which it ought to be every three or four hours, according to the child's constitution. The kind of food, however, ought to be varied according to circumstances, for one kind may agree well at first and disagree afterwards, and children of different constitutions require different kinds of food. In some children we must occasionally have recourse to light beef or chicken tea, mutton or other light broths, free from fat, and strained through a muslin rag, to which some of the different kinds of gruel above mentioned may be added. It must be carefully remembered, however, that whatever kind of food is found to agree best at this period, it must be entirely *fluid*, given *tepid* or *lukewarm*, and *freshly prepared every time the child is fed.*

As to the *quantity* to be given, that must depend greatly upon the child's constitution and habit of body; some children require double the quantity of food which will satisfy others; but we must take into account that the stomach at this age will only contain a few ounces, and every child has a tendency rather to eat too much than too little; much, however, will depend on the mode in which it is administered, whether or not too much will be swallowed by the child.

As to the *manner* in which food ought to be given to an artificially fed infant, before the teeth begin to appear, we must, in this respect also, endeavour to imitate nature as closely as possible. How, then, does *she* act? She, in the first place, affords a very *slow* and *gradual* supply of milk from the breast; the infant requires a considerable time to get its stomach filled, notwithstanding that it can hold only a few ounces,—at first, not more than half an imperial gill—and from this circumstance, and also because the child becomes fatigued by the exertion of sucking, it is not nearly so apt to overfill and overstretch its stomach, and to induce either vomiting of its food, or acidity, gripes, purging, or costiveness. In the second place, the exertion and motion of the lips, jaws, &c., in the act of sucking, excites an abundant flow of saliva, and this not only prepares the glands of the mouth to yield this fluid in proper quantity when solid food becomes necessary, but it is also said to assist the digestion of the food in the stomach.

Neither of these ends can be accomplished by feeding a child with a spoon; and we must therefore have recourse to some plan of more closely imitating nature. This can be tolerably well accomplished by using a properly constructed sucking bottle, which ought to have a narrow neck and a bulb at the extremity about the size of the nipple. The bulb should be covered with chamois leather, through which the infant can suck its food. The only objection to these bottles is the difficulty of keeping them clean; and unless they be so in the most perfect degree, the bad effect of their use will very soon show itself in the deterioration of the infant's health. The piece of chamois leather for the mouth should be kept constantly in spirits when not in use, and it should be exchanged for a new piece weekly. The bottle itself should be well rinsed out with warm water after every time the child is fed, and then immersed in pure cold water until it is wanted.

By the time the child has cut two teeth, food of a different kind will be admissable and necessary; it may then be fed with a spoon, and that management adopted which we are about to recommend as requisite for children before weaning.

From the principles above laid down, on which children ought to be fed, it must be abundantly evident that nothing but *liquid* food ought to enter the stomach of an infant till the appearance of teeth give indication that something in addition to the mother's milk is required, and that the period of weaning from the breast should be commenced.

As generally accomplished, the withdrawing of the child from the breast of the mother is *not weaning*, in the proper sense of the term, but an *abrupt transition* to which the child is subjected, in regard to its food, which ought never to take place. The period of weaning should last two or three months. It should commence when the child has cut two teeth, and terminate when it is perfectly able to live independently of any support from the breast of the mother.

In the first place, then, the interval between the times of giving the breast should be gradually lengthened, and at intermediate periods artficial food ought to be given, but still with the greatest regularity. The proper food to begin with will be that already mentioned, as the most suitable for a child which must be fed artificially; in quantity also about the same; but instead of the sucking bottle it may be fed with the spoon; the greatest care being taken not to cram the infant's stomach, and bring on indigestion and all its train of evils. It should be fed in a sitting posture, in small spoonfuls—for some time perfectly liquid and free from any thing solid—the food being introduced into the stomach in a very slow and gradual manner, and the child's expression and motions carefully watched so as to know when its appetite is satisfied.

In the second place, we must notice that artificial food is only to be given during the day; the child should be accustomed from the very first to be even fed at the breast at as long intervals as possible during the night, so as not to interrupt the mother's rest and thus injure her milk; and it ought on no account ever to be allowed the pernicious habit of falling asleep with the nipple in its mouth.

How often have we heard mothers complaining that their children had "*fallen off*" so much after weaning! From being healthy, happy-tempered, fat and plump, for the first five or six months while on the breast, they now wear a constant expression of suffering, and have become peevish and fretful, lean and emaciated. All these symptoms mothers set down without the least thought or investigation, to the effects of *teething*—little aware and hard to be persuaded that this change for the worse is the consequence of their own mismanagement. Fed, suckled, and put to sleep at all hours indiscriminately—the readiest and often the most indigestible food being employed—gorged at one time and starved at another—the deranged state of the bowels, which has been brought on by improper food and bad management, being unattended to—kept often in a state of filth, from soiled and wet clothes—it is not in the least surprising that the health and strength of the child should give way at the period of weaning; and when to all these causes of disease, we add confinement in close ill-ventilated rooms, insufficient clothing, and want of exercise in the open air, the number of children that survive such treatment at this period is a proof of the wonderful pliability of the infant constitution, and its capability of, in some degree, accommodating itself to circumstances the most adverse to continued existence. Life in these cases may be prolonged, but it will generally glow with such a feeble flicker as to be liable to be extinguished by any future blast to which it may be exposed.

SECOND EPOCH.—This epoch comprehends the period from the weaning of the child to the completion of the first dentition; or, from the end of the ninth, tenth, or twelfth month of its existence, to between the end of the second and the beginning of the third year.

General Management.—In most cases, by about the end of the first year, nature has supplied the child with the means of supporting an independent existence, in providing it with teeth. A marked change has now taken place in its physical development, both externally and internally. Its very external appearance has undergone a visible alteration. "At this time," says Wendt, "the hitherto projecting forehead becomes flattened, the countenance receives expression, the eyes intelligence, the limbs firmness." That sensibility of the general system, and nervous susceptibility, which are so characteristic of infant life, have become much less acute; the stomach and intestinal tube have become less sensitive, digestion is less rapid, food is less frequently required,

and a diet is now not only admissable, but absolutely necessary, which in the first stage of its existence would have been productive of the worst consequences. The activity of the circulation is lessened, the pulsations of the heart having diminished in rapidity, the growth is less active; the quantity of circulating fluids in the different organs is much smaller; and altogether, the bodily structures have acquired greater firmness, consolidation, and consistency, and have become better fitted for the various duties which they were destined to perform in the animal economy.

Under these altered circumstances, if the previous management of the child has been conducted on the principles of physiology and common sense, as above laid down, it enters upon this second epoch with its chances of arriving at maturity much increased in number, and its future treatment and management much lessened in difficulty. It has now nearly acquired the independent use of its limbs, and will give them exercise, in spite of every misdirected attempt to restrain them; it is better able to resist the over-cramming of its stomach, and can effectually check every effort to stuff it with food when it has no appetite, or when the stomach is disordered; and it can also in some degree give expression to its feelings, and give due warning when suffering from cold, hunger, or bodily pain.

Food in Second Epoch.—The proper feeding of children requires the exercise of the greatest judgment and discrimination on the part of their parents and nurses. If they supply them with food in too great quantity, or of two rich and stimulating quality, either the stomach is oppressed, indigestion produced, and the bowels overloaded and obstructed, followed by a numerous train of disorders; or, the excess of nutrition induces a too corpulent and over-full habit of body, giving the child an increased tendency to fever and inflammation—diseases to which children are but too prone without any such exciting cause. If, on the other hand, food is supplied to the child in too small quantity, or too meagre in quality, the body is imperfectly nourished, the growth is arrested, the various organs of the child became deficient in that health and vigour which is necessary for the purposes of continued existence; children fed upon a too low diet are very apt to become scrofulous, and to fall a prey to many of those diseases of which weak vital energy and a certain debility of constitution are strong predisposing causes.

No rule of diet can be laid down which would be found suitable in every case; scarcely do the constitutions of two children agree in every particular, and we must always modify the diet to suit the particular constitution of the child and the circumstances in which it is placed.

The same kinds of food may still be continued which have been mentioned above—farinaceous matter, mixed with milk, or weak broth free from fat; but it should now be given of much greater thickness and consistency; and by the time the child has cut four double teeth it has become enabled to chew food of some degree of solidity; no solid animal food, however, should be given till all the canine, or eye-teeth, are cut, which indeed is no great hardship, as broths and soups made from animal food contain sufficient nutriment for all the purposes of health and growth.

Man is an omnivorous animal; and it is found that a mixed diet of animal and vegetable food is the most suitable, in temperate and cold climates at least, in almost every case. With this the child ought to be provided, as soon as it has cut sixteen teeth, but in such quantity as not to overload the stomach, which can now contain nearly double the amount necessary, and of such quality as not to pamper and tempt the appetite to excessive indulgence. As long as the child is in good health, with a sound constitution, a clean tongue, regular bowels, and no symptoms of over-fulness, or a feverish condition of the system, its diet may be rather liberal, but plain; it ought, however, to be administered at regular periods of four hours to the generality of children of this age; and a child ought not to be allowed to acquire the habit of being fed during the night. But as soon as indigestion, over-fulness, or feverishness supervenes, with white furred tongue, headaches, thirst, heat of skin, &c., the diet must be immediately lowered and the animal food withdrawn; for some time even after these symptoms subside the child must be kept upon a restricted diet.

With children of weakly and delicate constitutions, a more scrupulous attention to diet will be necessary. They will require food at shorter intervals, but in less quantity, and of less stimulating quality than healthy, vigorous children, who can take much exercise; and even this restricted diet must be lowered when they fall into actual ill-health; at the same time, that every means must be adopted, under the eye of the physician, to restore the health and invigorate the constitution.

It is quite impossible to lay down rules of diet which are applicable in every case; children brought up in the country may be allowed more latitude in this respect than those living in towns; and many circumstances may occur to interfere with fixed rules, and make it necessary to depart from them in individual cases; the following, however, may be given as applicable to the majority of children in this epoch, in most ranks of life:—

The child will awake early in the morning with a keen appetite, which must be satisfied but not stimulated to over-indulgence. It may then be supplied with a little warm new milk, with minced bread soaked in it, and *slightly* sweetened with sugar; or it may have sago, arrow-root, or oatmeal, made into gruel with sweet milk; or, if the child be of a very weakly constitution, it may have some light soup, such as chicken-tea, mutton-broth, or beef-tea, thickened with bread or sago. As the child advances in age, this meal should be dispensed with, and breakfast given a little earlier.

After its appetite is moderately appeased, the child will sleep for some hours, and awake again ready for *breakfast* by nine o'clock. This may consist of the same ingredients; or it may have a little well-boiled oatmeal or barleymeal pottage with new milk.

One o'clock should be the *dinner* hour for children at this age, and even for several years afterwards. Dinner should consist of mutton, chicken, or beef broth, thickened with ground rice, sago, or fine pearl barley, as free from fat as possible; this diet may be alternated with one solely of farinaceous food. When the child has cut its eye teeth, it may be allowed a little solid animal food, such as beef, mutton, or fowl, not over-cooked, with a good potato, or some other fresh vegetable. For drink, nature points to water as the only safe beverage at this age, and it is the only one necessary.

At five o'clock, the child should have what may be called its *tea;* which should consist of a cupful or two of hot water and new milk in equal quantities, sweetened with a little sugar, soaked with bread or biscuit, for a young child, but as it gets older, the bread should be eaten with the hand. If the child is delicate, it may have a little weak tea. At seven or eight o'clock, the child is ready to go to sleep for the night, and about this time it should get the same food as it got for its first meal in the morning.

The periods of giving food ought to be fixed and invariable, and no eating, even of half a biscuit, should be allowed between meals. An error which inexperienced mothers and nurses are very apt to fall into, is to give the child food every time it cries. A child may have many different causes to make it cry besides hunger; it will even cry sometimes for want of anything better to do, if it is not properly attended to or amused, and then it will eat to appease, not its *hunger* but its *langour.* Such treatment will soon induce derangement of the stomach and bowels; medicine will be required; and if the cause be not removed, the health and constitution of the child will be ruined for life.

"The most objectionable articles of food for children," says Sir Anthony Carlisle, "are the indigestible parts of fruit, unripe fruit, salads, all uncooked vegetables, sugared pastry, nuts, cheese, veal, pork, and stewed meats."

Clothing.—The great object of clothing is to afford due warmth to all parts of the body; it ought to be of such texture as to combine warmth with lightness and softness of material; and it ought to be made in such a manner as not

to interfere with the free movements of the body, and to occasion no unnatural constriction on any part. One of the greatest causes of bodily deformity, of stiffness, and awkwardness of gait, is tight fitting clothes on children. It is invariably remarked by travellers, that among nations where fashion prescribes loose and flowing robes for the bodily covering, there are fewer examples of deformity, and a grace, elegance, and noble demeanour in walking, and the performance of all the bodily movements, that are in vain looked for where the caprice of fashion leads to the adoption of clothing which impedes the natural movements, checks muscular developement, and deforms the human figure.

No more absurd and pernicious notion ever entered into the heads of parents than that of fancying that they could strengthen the constitutions of their children, and "*harden*" them, as they call it by inuring them to cold, and exposing them thinly clad to all the severities of the weather.

"The present fashion of clothing young children," says Dr. Clarke, "founded upon the erroneous notion of hardening them, is very injurious to their health. Their arms and chests are entirely uncovered. They generally wear no stockings at all; and, from the stomach downwards, they are almost in a state of nakedness even in winter.

"To rebut the force of these objections, this question has often been asked, What becomes of the children of the poor? * * * But, if they inquire, they will find that comparatively few of the children of the poor are reared."

It is invariably found that the families who are best clad and least exposed to cold and damp in winter, are the most healthy; while those, who from necessity or choice, are condemned to undergo the hardening process, are seldom free from disease. "Disorders, which otherwise might have lain dormant, are thus brought into activity by this mode of treating children; and many fall a sacrifice to pulmonary consumptions and scrofulous complaints in more advanced life from this error alone, of heing exposed in childhood to cold with the intention of being made strong and hardy."*

Cleanliness.—Few things are of greater importance in the proper management of infancy and childhood than strict attention to cleanliness. A great accumulation of solid and liquid matters are thrown out of the system, through the skin, every twenty-four hours, in addition to the dirt which collects upon its surface, from dust, smoke, &c., from without. If these matters are not thoroughly removed, at least once, but far better twice, daily, the effects of its presence will soon become evident. Distressing excoriations, cutaneous eruptions, which are difficult to heal, and other diseases follow inattention to this particular; even the growth and vigour of the child will be checked, and its constitution permanently debilitated.

From a very early age it is quite possible, by watchfulness and attention, in the first instance, to teach the child cleanly habits; if it is properly managed as to its food and sleep, the howels and bladder will be evacuated with the greatest regularity, and symptoms of a desire to perform these offices can very soon be detected. If this regularity is encouraged, the mother will save herself an immensity of trouble, and her child a great amount of vexation and annoyance; nay, even this very habit of regularity will have a great effect on the future health and welfare of her infant.

The soiled clothes of children ought to be very often changed; if possible, the inner clothing should be renewed daily, and when once soiled and wet with urine, &c., it should never he dried and put on a second time.

A child of this age should be sponged with cold water and a little yellow soap every morning, particular attention being paid to its armpits, flexures of the joints, &c.; its hair should be carefully combed and brushed; its eyes, ears, &c., thoroughly but gently washed and dried; and its teeth ought to be brushed daily with a soft brush.

Sleep.—Children require much more sleep than adults; and the younger the child the more sleep it requires; but up to the third or fourth year of their age, children should be allowed an hour or two's sleep in the middle of the day.

* Dr. Clarke's Commentaries on the Diseases of Children.

Regularity in the hours of going to sleep, as well as in every other particular, ought to be scrupulously attended to by all who wish to rear a healthy offspring. The child should be always accustomed to retire early to rest and be allowed to get up in the morning as soon as it awakes of its own accord. But on no account should a child be curtailed of its hours of sleep and roused in the morning sooner than it awakes spontaneously; one child requires more sleep than another, and children in general are more complained of for wakening too soon, than of sleeping too long.

The sleeping-room should be large and well-aired, but it should, at the same time, be warm and free from draughts. The child's bed ought to be without curtains; and it should lie upon some firm and elastic material—such as a small tick, stuffed with straw, which can be frequently dried and exposed to the sun and air. By and by, a hair mattrass will be necessary as it advances in age.

Air and Exercise.—The child now begins, if at all in good health, to feel an irresistible impulse to use its limbs in attempting to walk; its legs and arms are in constant motion; it seizes everything it can lay hold of, and expresses unequivocal signs of wishing to crawl on all fours. As we have already said, these movements, its crawling, its grasping objects, and its endless and varied bodily motions ought on no account to be checked or interfered with in one way or another. Every movement is the manifestation of one of nature's laws, and every obstruction to, or improper interference with, any of these laws is invariably followed by punishment. A child, unless improperly urged, which ought never to happen, will not take so much exercise as to induce over-fatigue; but its parents and nurses are often so delighted to see it beginning to acquire the use of its limbs, that they improperly encourage it to carry its exercise of them to excess. They must be reminded, however, that at this age the bones of its legs are soft and flexible, and if urged to sustain the weight of the body beyond a proper length of time, they will become bent and deformed.

As the age advances, the child must be allowed daily exercise in a garden or field, when it will have a sufficient amount of it in running about at its plays; and this, too, with much more benefit than when urged by an injudicious nurse to take a monotonous walk on a straight road. The child ought to be allowed perfect freedom to run about in the fields, if living in the country; and, if in town, it ought to be carried out quickly to a proper place at some distance, and then allowed to run and play about for a longer or shorter time, according to the state of the weather. One of the most pernicious plans which can be adopted by a nurse is, when she is giving it what she calls out-door exercise, to prevent the child using its legs at all, but to keep carrying it, while she stands or saunters about gossiping with her neighbours, the child at the same time, not only having its legs and lower parts of its body confined and squeezed in her arms; but, if the weather is cold, it is chilled to such a degree as frequently to give rise to catarrhs, croup, or inflammations, which either terminate its existence or impair its constitution for life.

LARGE SHEARS WITH A CONTINUED MOVEMENT.

BY M. FREY, MECHANICAL ENGINEER AT BELLEVILLE.

M. Frey, who devotes his attention to the construction of various ingenious machines, has executed for the workshops of the Northern Railway in France, and for other establishments, several machine-tools of useful application; and, in particular, a system of shears, with a continued movement, which is now employed with advantage in various mechanical operations.

M. Cavé, at Paris, Mr. Nasmyth, in England, and M. Nillus, at Havre, have likewise for several years been engaged in constructing machines of this description, which are very useful, either for cutting thick bars of iron, as rails, wheel-

tires, &c., or for cutting plates of sheet-iron for boilers, water-cisterns, steamboats, &c.

The arrangement of the shears is very simple, as may be seen by the annexed figures—

Fig. 1.

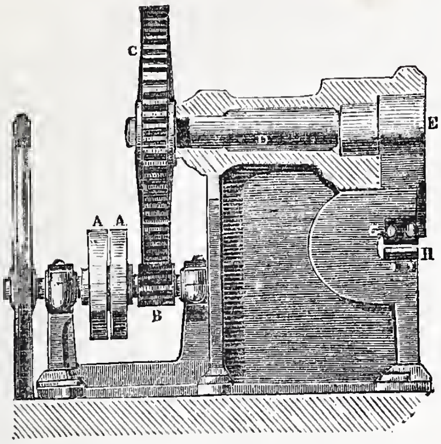


Fig. 1 is a lateral elevation of the machine, with the upper part of the framework cut away to show the principal arbor of the shears.

Fig. 2.

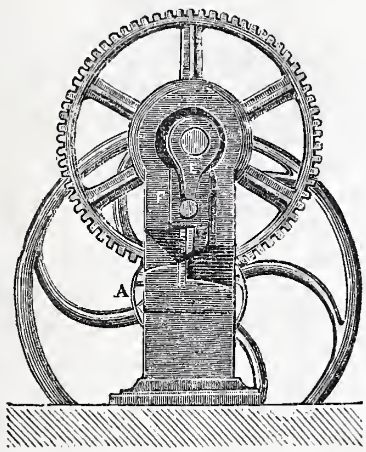


Fig. 2 is a front view of one side of the knives.

The motive arbor of this machine carries, at one part, two pulleys, A and A′, one of which is fixed on the axis, to communicate a rotatary movement, and the other is loose, to interrupt this movement at pleasure; it carries also a regulating fly-wheel, and a broad toothed pinion, B.

The latter gears with the large cast-iron wheel, C, which is mounted at the extremity of the principal axis (of wrought-iron), D, carrying at its other extremity a kind of handle, E. This last, which is rounded off at its lower part, is received into a cavity of the same form, near the bottom of the strong sliding-piece, F, which is armed with a steel-blade, G, moveable like itself. A similar blade, H, is fixed on the foot of the framework in which the apparatus is fitted.

The plate or bar to be cut, on being presented between these two blades, is divided neatly and without effort, when the one descends on the other by a slow and continuous motion.

The power with which the machine acts is such that one can cut, without difficulty, bars from half an inch to an inch in thickness, and from two to three inches in breadth, and more.

IMPROVED CORF-BOW AND HOOK.

By Stephen Reid, Esq., Newcastle-upon-Tyne.

The object of this improvement is to avoid the series accidents that have occurred at colleries, by the use of imperfect corf-bows, or handles, and hooks, by which the corfs are suspended.

Fig. 1.

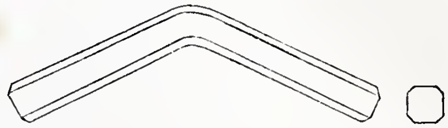
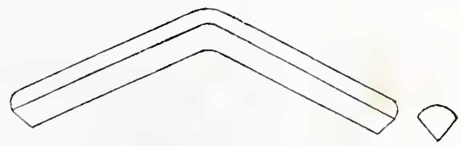


Fig. 1 is a side view and section of the old bow, being a square with the corners taken off. Fig. 2, a side view and section of the improved bow the under side being bevelled to an edge.

Fig. 2.



This plan almost inevitably secures the proper hooking of the bow; for, being an edge, it slips at once upon the hook, if it once be over the point; whereas, in fig. 1, the under surface being flat, the point of the hook may, and often does, hold by that surface, instead of the bow being fairly lodged in it. Figs. 3 and 4 are two views of the improved hook. When the bow

Fig. 3.

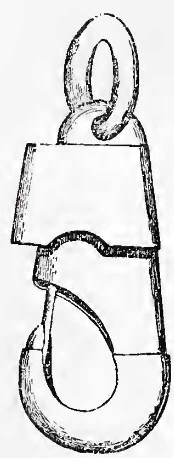
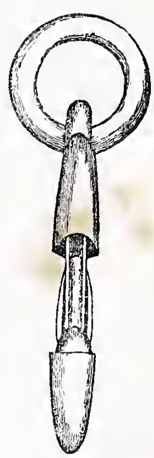


Fig. 4.



is put on it, and slips into the bend, a slide comes instantly down, and fastens over the tongue of the hook, as well as the shank. This slide is secured in its place by a knatch protruding from the inner part of the hook through an aperture in front, and which, being acted upon by a spring which keeps the tongue in its proper place, secures the slide, no matter in what direction the hook may be moved. Of course, this hook is applicable to many other uses besides the specific use for which it was invented.

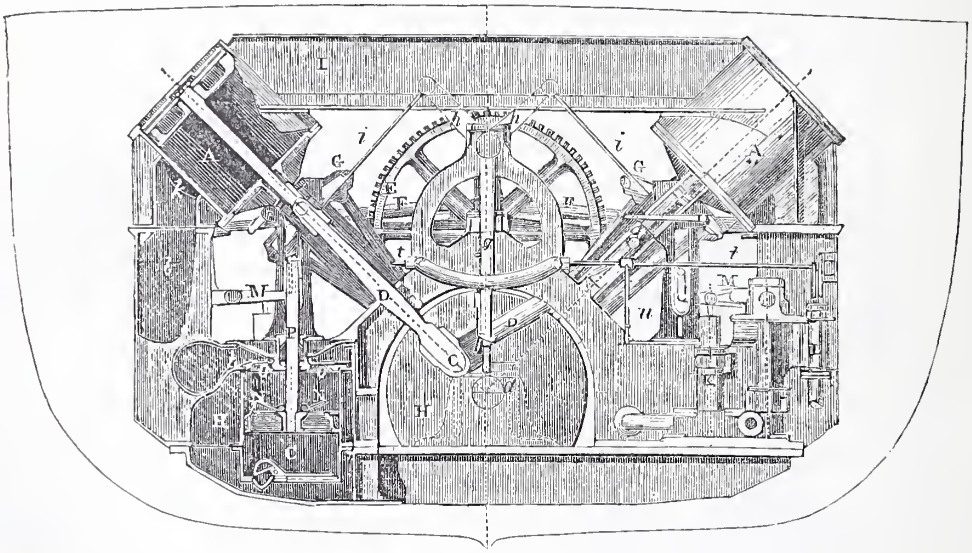
GEARED MARINE ENGINE FOR THE SCREW PROPELLER.

By Messrs. Stothert, Slaughter, & Co.

This engine, which is intended to combine the advantages of a direct-action quick-working engine, with those of the indirect slow-working engine, attracted considerable attention in the engineering department of the Great Exhibition in 1851. Its characteristic features are these: the cylinders, as shown in the annexed engraving, are disposed at an angle on each side above the screw-shaft, to which the motion is communicated directly from the pistons; and on the screw-shaft is a small spur-wheel gearing into a wheel of larger diameter directly over the screw-shaft centre, and carrying pins to work connecting-rods, which communicate with bell-crank levers for working the air-pumps. This engine, in combining the advantages of the direct and indirect action engines, claims at the same time to avoid the disadvantages of both.

To attain the best possible form and angle of screw, it is considered desirable, in some cases, to give a speed to the propeller shaft, which is too great for the proper working of the vacuum, supply, and bilge pumps. An undue amount of wear and tear, as well as loss of power, attaches to the rapid opening and closing of the large and numerous valves required for the passage of water—so much so, that some of the most eminent engineers of the day have, chiefly on this account, preferred the indirect engine, with its complex and costly gearing, to the light and inexpensive direct-action engine, which has otherwise decided advantages. This was more especially the case before the introduction of valves of vulcanized india-rubber, which, since the patent for the present engine was taken, have come into general use, and which permit the application of a higher speed to those parts of the engine that work the vacuum pumps. Still the marine engine of Messrs. Stothert, Slaughter, & Co., has many peculiar advantages which highly recommend it for adoption in connection with the screw propeller.

In this engine the steam-cylinders, A A, are elevated on each side of the screw-shaft, at an angle of 45° with the horizon. The connecting-rods, D, are jointed at one end to the piston-rod cross-heads, *a*, which work between guides, as shown in the figure; the opposite ends of the connecting-rods are keyed to a pin, *c*, upon the circular plate, H, which is fixed to the screw-shaft. The slides are worked from eccentrics at *d*, through eccentric rods which are jointed to the extremities of the reversing links, G, and from these the valve spindles pass to the valve chests. The reversing links, G, are actuated by the reversing handle, *g*, which moves the crank-arms, *h*, and pendant rods, *i*. The exhaust steam is conveyed through the hollow belt, *k*, and exhaust-pipe, *l*, shown internally on the left of the figure, to the condenser, B. In this condenser is the air-pump, C, the valves of which are metal flap-valves. The water and air from the condenser are admitted to the interior of the pump by the valve, *m*; *n n* are similar valves in the air-pump piston; *o o* are the exit valves to the passages, *p*, leading to the hot well.



Partly Sectional Elevation of Combined Marine Propeller Engine.

From this description of the principal details of the engine, the reader will easily perceive how a diminished rate of motion is communicated to the air-pump piston. On the screw-shaft, as already stated, is a small toothed wheel, gearing into another wheel, E, the diameter of which is three times larger than the former. A crank-arm on the axis of the wheel, E, gives a reciprocating motion through the connecting-rods, F, to the bell-cranks, M, one arm of which is connected by links to the extremity of the air-pump piston-rod, P.

It is evident, from this arrangement, that the speed of the air-pump piston is regulated according to the difference in the diameters of the two wheels. If the wheels, for instance, are as three to one, as in the specimen engines shown at the Great Exhibition; and if the screw-shaft have a speed of 120 revolutions per minute, the air-pump piston will make but 40 strokes per minute.

The feed-pumps, K, for forcing the water into the boilers, are worked by cranks upon the axis of the bell-crank, M. L are hand-pumps worked through the rods, *t*, by the lever handles, *u*. The framing, S, is securely bolted together, and, with the cylinders, is cast in as few separate pieces as possible.

By this arrangement the speed of the vacuum apparatus is diminished to any required extent, and thus the difficulty of keeping a proper vacuum at the speed required for direct-acting screw engines is overcome, even with the use of metal valves; but vulcanized india-rubber valves may be used with additional advantage in this engine also, which, from its compactness, and other qualities, is peculiarly well adapted for the merchant service.

NATURAL PHILOSOPHY AND CHEMISTRY.

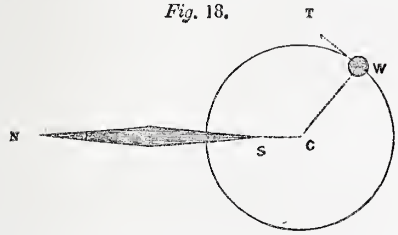
CHAPTER XXV.

ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART II.—ELECTRO-MAGNETISM—*Continued.*

46. IT follows, from geometrical investigation of the direction of the force derived from the joint action of the poles of the needle by which the wire is impelled, that the wire is in every situation urged to move in the direction of the tangent of a circle whose centre is to be found in the extension of the axis of the magnet, and whose radius is a mean proportional between the distances of its centre from the two poles. For instance, in the annexed figure, the wire W is urged, by

Fig. 18.



the united influence of the poles S and N, in the direction of the tangent T W of a circle whose centre is at C, which is a point in the line of the magnet extended, and the radius C W of which is a mean proportional between C S and C N. The wire will therefore revolve in that circle which will bear the same relation to the poles N S, with reference to the law of ELECTRO-magnetic action, that the magnetic curves possess with respect to the law of MAGNETIC action.

47. The entire science of which we are treating may be considered to rest upon the principles heretofore developed, which afford the means of explanation of a mass of facts, many of which would appear contradictory and perplexing without an accurate application of those principles to the varying circumstances of the case. By them, Professor Oersted's results, which for a long time appeared inexplicable, are now brought clearly within our comprehension.

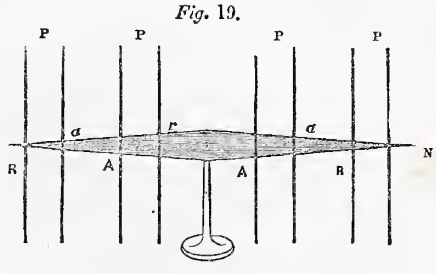
48. The reader will remember that in Oersted's experiments, the wire was placed in a horizontal position, either above or below the needle, and parallel to it. Under these circumstances, the force of the current passing along the wire is directed in the line of a tangent to the circumference of a VERTICAL circle which has two wires for its axis; and this force, acting upon the *two* poles in opposite directions, induces a motion of the needle round this axis. The needle, however, having previously a tendency to dispose itself in the plane of the magnetic meridian, in consequence of the earth's influence, will place itself in a position intermediate, between the meridian plane and that to which the influence of the current induces it, its deviation from the magnetic meridian being in proportion to the intensity of the electro-dynamic influence; and the amount, as well as direction of the deviation, will, on examination of Oersted's results, be found to be precisely what theory indicated.

49. Furthermore, when the wire, being still horizontal, was placed by Oersted at right angles to the needle, and over its centre, no perceptible effect took place, because the action of the current on the north pole, and that on the south, were exactly equal. When, however, the wire was moved nearer to one pole than to the other, the vertical action exercised of course a greater influence upon the *nearer* than upon the remote pole, and consequently caused its elevation or depression, according to the direction of that *greater* influence, in a manner exactly accordant to the anticipations of theory.

50. The observations of Mr. Faraday with respect to the action of the conducting wire placed perpendicular upon a horizontal needle, may be now properly noticed, those observations having afforded a clue to some of the most important and striking illustrations of that particular theory of tangential action, which is looked upon with most favour by English philosophers. Mr. Faraday found, upon approaching a horizontal needle to a perpendicular wire conveying the current, with the view of determining its positions of attraction and repulsion in relation to the wire, that in place of these positions being only four—namely, one of attraction and one of repulsion for each pole—there were eight; viz., *two* attractive, and *two* repulsive. For instance, supposing the needle to have previously arranged itself in its position of equilibrium ACROSS the wire, from which, in that position, its poles would be equidistant, and the support of the needle to be parallel to the conducting wire; if the centre of that needle were drawn away from the wire, so as to bring either pole towards that wire, or nearer to it, in the case of the north pole, there was attraction; but on approaching that pole yet nearer, so that the end of the needle was closer to the wire than the centre, repulsion took place, *although the wire continued on the same side.* But when the wire was at the *other* side of the north polar half of the needle, it repelled it at almost every point between the centre and the end; but at the *very end* there was found to be attraction.

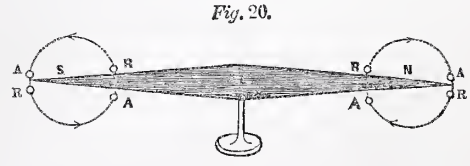
51. In order to enable the reader to comprehend more clearly these apparently anomalous and singular changes of electro-dynamic influence, we subjoin a figure illustrating the relative positions of the needle and wire during their occurrence.

Fig. 19.



In this figure, the current is supposed to be descending along the conducting wire, which is placed in eight different positions; four of these being on the near side of the needle, and four on the remote. The letters A, *a*, denote the attractive action, and R, *r*, the repulsive action occurring in each position. These facts find their explanation in fig. 14, and its explanatory paragraph (37, p. 251), and will appear sufficiently intelligible, provided we take into consideration a circumstance which is almost always found to occur in *pointed* needles similar to those depicted in the figure—namely, that the position of the centre of the most active portion of each half of the needle, or its *true* pole, is not to be found at the very extremity, but at a point at some distance from it, towards the centre of the needle. For this reason, the wire, when placed close to either extremity of the needle, was *beyond* the poles, and thus occupied a position similar to that of the wire represented in fig. 14, when external to the circle passing through the true poles of the magnet, which may be assumed to be the circle in fig. 14.

Fig. 20.



52. Mr. Faraday also illustrated the reaction of the needle on the wire in the above situations, which the reader will comprehend on reference to the annexed figure, which exhibits horizontal sections of the wire placed in different situations

with respect to the needle balanced on a central pivot. These positions are denoted by the letters A or R, according as the wire in such positions has an apparent attractive or repulsive influence with respect to the adjacent poles S, N; and the direction of the circular motion which resulted is represented by the arrow heads.

53. The conclusion drawn by Faraday from these observations is, that there is NO REAL attractive or repulsive influence exercised between the conducting wire and either pole of a magnet; but that the actions which resemble such effects are COMPOUND in their nature. He was also led by these considerations to the conclusion, that if the action of a single pole could be exercised *without* the interference of the other, the conducting wire ought to revolve round either pole of a magnet, and either pole of a magnet round the wire, if proper effect could be given to their natural tendencies.

54. We are indehted to Dr Wollaston for the first idea of the possibility of producing electro-magnetic rotations; for, considering that the conducting wire acted differently according to the side which was presented to the magnet, that which was attracted by one side being repelled by the other, and that if this influence were produced by the impulse of a *fluid*, that fluid must be continually circulating round the wire in a description of vortex of which the wire was the axis; he conceived that the consequence of such a VERTIGINOUS motion in the supposed electric or magnetic fluid, would necessarily develop rotatory motion in the constituent parts of certain arrangements of magnets and conducting wires. Dr Wollaston's own experiments in support of these notions were not successful; but his suggestions were shortly realised by Faraday's discovery of the rotatory motions which he had predicted. By adopting mercury as part of the voltaic circle, so as to allow of unrestricted motion in the conducting wire, or conversely in the magnet, in such a manner as to limit the action to one pole only, Faraday succeeded in producing a variety of rotations, as well in the magnet as in the wire. On sending an electric current down a perpendicular wire, the north pole of a magnet moving in mercury, and also perpendicular, or nearly so, revolved round that wire in the direction of the hands of a watch; and on fixing the previously moveable magnet in the centre, and giving freedom of motion to the conducting wire, the wire was found to revolve in the same circular direction.

55. The reader will bear in mind, that in all these rotatory motions, the direction of the motion depends on the direction of the current, and on the particular magnetic pole which is influenced by it. If the current be *descending*, the north pole of a magnet rotates in the direction of the hands of a watch, or from left to right; if, on the other hand, the revolving pole be the south, the motion of that pole will be from right to left, or in the contrary direction to the hands of a watch;—all these movements being perfectly accordant to the principles explained and illustrated in preceding sections and figures.

56. In consequence of the resistance presented by mercury to the revolution of the magnet, various attempts have been made to devise instruments which, while they exhibit the desired effect, shall be free from the inconvenience attending Faraday's arrangement. Many of these attempts have been successful; and various beautiful instruments, some of them being combinations of the more simple forms of the experiment, are now constructed, and daily improved upon, which, however, we do not consider it advisable to describe in this place, deeming it preferable to wind up this treatise with a chapter descriptive of the best forms of the instruments intended to illustrate the principles and simple diagrams contained in the preceding chapters.

57. Subsequently to the discovery of the rotatory motion of the magnet round a conducting wire, and of the wire round a magnet, various philosophers attemped to obtain the rotation of a magnet, or of a conducting wire round their own axis; but Ampere was the first who succeeded in developing this effect in a perfect manner. In his original experiment, the magnet floated in mercury, being kept in a vertical position by a weight attached to its lower end; and the current was cut off after passing along one half of the magnet, so as to limit its action to that half of the magnet, or rather to confine the operation of its influence to the pole contained in that half only. Various improvements have been made in the illustration of this interesting discovery; but the principle, which in all is the same, and upon which the phenomenon depends, is this,—that the current should descend through the upper half of the magnet only, so as to limit its influence to that pole which is situated in that half, and afterwards be conducted away in such a direction, as that it shall not take any effect upon the other pole. In the application of this principle to the instrument invented by Ampère, the current, after passing along one half of the magnet, enters the mercury surrounding it, through which it is diffused, and in consequence does not exercise any perceptible influence on the lower pole of the magnet, nor interfere with the rotation produced by its influence on the upper pole. There are other circumstances connected with this phenomenon, which should be considered in explaining its nature, but which we are not yet in a position to bring intelligibly before the reader: it will, however, be again adverted to in a future chapter.

58. Ampère having thus succeeded in making a magnetic body revolve upon its own axis, it appeared reasonable to conclude that a non-magnetic body, conducting electricity, might be similarly influenced: but inasmuch as, in the former case, the electric principle had to be applied in the *interior* of the revolving magnet; so, in the present case, it became requisite to procure the action of the magnet from the *interior* of the conducting substance. This, of course, could not be accomplished with the conducting wire; and therefore Professor Barlow employed in its place a hollow cylinder of metal, into the axis of which the pole of a magnet could be introduced. This cylinder rested on a pivot, and its lower edge touched a reservoir of mercury which surrounded the magnet as in the former instance, the magnet itself being separated from the cylinder by insulating substances. In this arrangement, the descending current, being unable to traverse the magnet, has no other channel than the copper cylinder, down which it must descend into the mercury, and pass thereout by a wire communicating with the battery. This cylinder may therefore be considered as a collection of wires parallel and contiguous to one another, each of which receives from the pole of the magnet, placed in the interior, motory impulse in a direction parallel to itself.

59. Those wires on opposite sides of the magnet will be impelled in opposite directions; but as their forces operate on opposite sides of the centre of motion, they will all agree in the effect produced. The entire cylinder, which we assume to be composed of a number of parallel wires, will therefore be found to commence revolving as soon as the current passes; and as the resistance presented by the mercury to its lower edge is very slight, it will soon acquire considerable velocity; and, under the circumstances already explained—that is, when the current is *descending*, and that part of the magnet *within* the cylinder, the north pole,—the direction of its motion will be from left to right.

60. When either of the above conditions is reversed, the motion will be also reversed, which may be illustrated by employing a horse-shoe magnet, with its poles uppermost, and supported on a stand in a vertical position. A cylinder similar to that already described may be suspended upon the extremity of *each* pole by an insulating substance, and play in a wooden trough surrounding each limb of the magnet, and containing mercury. Upon a current being sent from the battery, *up* one cylinder, and *down* the other, the rotations arising from the contrary influences of the two poles, will be in the *same* direction in *both* cylinders; but if the current be sent in the *same* direction in both cylinders, they will revolve in a *contrary* direction, being actuated by opposite influences exerted by the poles within them.

61. It appears from the result of Barlow's experiment, detailed in paragraph 58, that the electro-magnetic influence of the conducting body is the same, no matter whether the current be equally diffused over an extensive surface, or be concentrated on a single wire—the only difference being, that the effects will of necessity be *weaker* in proportion to the extent of diffusion; but when the entire of these diffused currents are concentrated, and brought to bear upon the production of any effect, the result will be the same as if they had been originally limited to a single wire. It will be thus understood how every wire constituting the cylindrical *whole*, however attenuated we may imagine it to be, will conduct its special portion of the original current, and contribute to the production of one general effect, which, in the instance before us, is the revolution of the cylinder.

62. In the same manner, it has been found that the current which is passing through the battery itself, from one extremity to the other, will produce electro-magnetic properties similar to those exhibited while it is passing along the *external* wire connecting the same extremities. Therefore, as all action implies a corresponding reaction, we are justified in inferring that magnetic action would move the battery; and *this* experiment has proved to be the case.

CHEMISTRY OF ORGANIC NATURE.

CHAPTER III.

THE ANIMAL KINGDOM.

OF DIGESTION.—PREPARATORY STEPS.

The food prepared by nature for many animals, when they first make their entrance into the world, is a fluid which, as has been already stated, consists of substances that are found in the animal nourishing them, either in the state in which they were originally introduced into the digestive apparatus, or in a slightly modified form. From a quantity of milk, therefore, it must be obvious to every one, that animals increase in size and in weight—or, in other words, they are formed from this fluid. The same observation applies to flour, which, we have previously stated, contains all those matters which are found in the animals which feed upon it—sometimes unchanged, and sometimes in a modified form. It hence becomes a most interesting inquiry to make ourselves acquainted with the nature of this fluid and this powder, upon which the existence of so much of animated nature is dependent. The following table affords a parallel view of the ingredients of the two bodies:—

Flour.	Milk.
Fibrin, Albumen, Casein, Gluten	Curd or casein.
Oil	Butter.
Sugar, Gum	Sugar.
Water	Water.
Salts	Salts.
Starch.	

The only ingredient in the flour for which there is not an exact parallel in the milk is starch, which, however, differs from oil or fat merely in the quantity of oxygen contained in it; and hence the idea at present entertained by some chemists is, that the starch of flour, by undergoing in the animal system a deoxidating process, is converted into fat, which again acts an important part in the operation of breathing.

The fibrin, albumen, and casein, approach very near to each other in composition. The oil is a fatty body, which, however, has not been accurately examined; but as all oils and fats are similarly constituted, the transformation of one into another modified form can be easily understood. The following table exhibits a comparative view of the composition of such of the constituents of flour as have been accurately analyzed:—

	Fibrin.	Albu.	Casein.	Gluten.	Sugar.	Gum.	Starch.
Carbon	53·23	53·74	53·46	53·27	36·36	42·58	44·26
Hydrogen,...	7 01	7·11	7·13	7·17	7·09	6·37	6·70
Azote, ...	16·41	15·65	16·04	15·94			
Oxygen,.....		23·50	23·37	23·62	56·55	51·05	49·04
Phosphorus, Sulphur, ...	23·35						
	100·	100·	100·	100·	100·	100·	100·

Fibrin is well characterized in the lean part of beef; albumen, in the white of the egg; and casein, in the curd of milk.

Such, then, are the main constituents of the food which nature has supplied for the purpose of supplying the waste which animated beings are continually undergoing. It has been a subject of much debate among metaphysicians, whether animals obtain a knowledge of the food proper for nourishing them by their experience, or by means of some mystical power which they term instinct. It is quite certain that experience alone is the guide of human beings; and it seems rather a stretch of reasoning, to attribute a *higher* power to *inferior* animals. Be this as it may, there is a law implanted in the animal economy which regularly, at intervals, brings to mind the necessity that there is for taking food. This law is commonly termed the sensations of

I.—Hunger and Thirst.

These are the preliminary steps to digestion. They constitute a law of animal life, for the purpose of inducing living beings to take such nourishment as is required to supply the waste which they are continually undergoing. If the dictates of these sensations are rationally obeyed, satisfaction and healthy digestion are the result; but if, on the contrary, they are disobeyed, weakness and disease must necessarily ensue. A physician was consulted by a worthy missionary, previous to his departure for India, with regard to the propriety of fasting as a religious observance. The former told him, that he considered the sensation of appetite and hunger as a most important law in the animal economy, destined by the Creator for the purposes of existence. It was therefore a law of God, that it ought to be obeyed as a matter of duty; and that, if infringed, the consequences would necessarily be in a greater or less degree prejudicial; for it is no argument in favour of any such experiment upon human life, that life does not terminate upon its adoption, or that the symptoms of some frightful disease are not instantly ushered in. The seeds of future mischief may be sown in one experiment, and may only lie dormant until a second or succeeding infringement shall cause them to sprout forth into living activity. One instance of abstinence or of drunkenness may not produce death or immediate disease; but in one day of want or inebriety, the constitution may be irremediably ruined; and, at the very least, the subject who has been guilty of such deviations, must be pronounced as having attempted to thwart unchangeable and eternal laws. Similar reasoning is applicable to the poor who are unable to procure sufficient food to appease the important sensations when they occur. We have every reason to infer that disease will be engendered by these unwilling but necessitous fastings. How incumbent, therefore, is it on those who are in better circumstances, to prevent the occurrence of such disease, by contributing to the support of their fellow-beings!

Appetite, or, in its more advanced stage, *hunger*, teaches animals to seek for solid food; and *thirst* suggests the propriety of rendering the solid mass more pulpy and dilute, by the employment of drink. Experience and reason, we conceive, must distinguish the proper objects to be employed for such purposes.

II.—Mastication, or Chewing.

When a solid portion of food is seized by the front teeth, it is conveyed into the cavity of the mouth, by the assistance of the lips, jaws and tongue, and the auxiliary muscles. By aid of the tongue, it is placed between the opposing jaws, where it is ground to a proper consistence. But the action of the jaws in grinding the morsel introduced between them, at the same time calls into play the compressing power of the muscles of the cheek upon the parotid gland, which is placed before the ear, and expels its secreted fluid, the saliva, into the mouth, to assist in comminuting the nutritive matter. Besides this mechanical agency, there is however a nervous action called into operation; the masticated matter acts upon the tongue and adjacent parts, inducing a sympathy with the glands placed under the tongue, and causes them to pour out their copious contents. The object of mastication, or chewing is, therefore, to reduce the food to such a consistence as shall fit it for its reception and proper digestion in the stomach; this is well illustrated in the instance of animals which are not supplied with teeth. The common fowl, for example, has no teeth; but it has a muscular apparatus called the gizzard, which powerfully compresses the introduced food, and by means of pebbles and stone, which are a necessary article of food with the class of animals referred to, an artificial substitute for the teeth is provided. From attention to these facts, therefore, we are taught that the preparatory step of digestion consists of the comminution of solid food, by means of the apparatus set apart in the mouth for this purpose, and its mixture with a certain quantity of fluid to render it more dilute. Two questions arise from reflecting upon these circumstances. These are, what ought to be the nature of the solid food introduced, and of the liquid, which our sensations may require, in addition to that supplied by nature? The first question has been long ago solved by Dr Prout, who directs us to nature herself for an answer to our question. Milk is the food provided at first for the use of man. The study of the composition of milk will throw light upon what ought to constitute the proper food of man. Milk contains four alimentary principles: *water, sugar, albumen,* and *oil.* Water, it has been asserted, affords no nutriment. And yet the human body consists of three-fourths of water; for without it, matter, in its solid state, appears incapable of vitality. One great antagonist to the organization of water, and therefore to vitality, is alcohol, which we find attracts the water, and causes the wretched mummy-like aspect, so distinctly observable in drunkards. Under *sugar* are included starch, and the other products resulting from chemical change in sugar: it comprises vegetable food. *Albumen* includes animal food, under its different modifications. The inferior nutritive food belongs to the class of oils, which are difficult of digestion, and in this country, comparatively rarely resorted to, with the exception of alcohol, which is most closely allied to the vegetable oils, the least nourishing of its class. The resolution of the second question, with respect to the nature of the liquid which ought to be introduced in contact with the solid food, directs us to the consideration of the saliva, which is the natural diluent to the food, and is supplied by the salivary glands. All the fluids of the human body present but an insignificant quantity of solid matter, in proportion to the fluid part; accordingly, we find that the saliva contains ninety-nine and one-third per cent. of water, the remainder being principally common salt and mucus. If we therefore follow the rules which nature has laid down, it would appear that water is sufficiently stimulating for the purposes of diluting the masticated food, and preparing it for its digestion in the stomach.

The *saliva*, or spittle, is a frothy fluid, considerably heavier than water. During eating it is said to be alkaline; at other times acid. The saliva is supplied by a gland in front of the ear, termed the *parotid gland*, which is familiarly known in an inflamed state in the disease termed the mumps. Saliva is also poured into the mouth from various small glands placed under the tongue. The quantity emitted in twenty-four hours, from the various glands, is computed to amount to $1\frac{3}{4}$ lbs. troy. After being filtered, the saliva is clear and colourless. When evaporated, it leaves from 1·12 per cent. to 1·8 per cent. of residue. It consists of the following substances, according to two analyses:—

Water,	98·878	99·29
Animal matter,	0·626	0·29
Muriate of lime,	0·180	0·14
Lactate of potash,	0·095	
Lactate of soda,	0·024	
Mucate of soda,	0·164	
Phosphate of lime,	0·017	
Saliva,	0·015	
Common salt,		0·17
Soda,		0·02

It has been thought that in the healthy state of the body the saliva should be neutral or alkaline, and that in persons who are troubled with indigestion, in which acid is developed in the stomach and in the upper part of the canal leading to it, we have an explanation of the rapid decay of the teeth in persons so affected. Certain it is, that in decayed teeth, the inorganic matter, consisting of phosphate of lime or bone, earth, and chalk, has been in a great measure removed, and the principal part of the residue consists of animal matter, or cartilage, which is insoluble in such acids as make their appearance in indigestion.

TEETH.

Various opinions have prevailed with regard to the structure of the teeth. Hippocrates conceived that they were formed of hardened fat; Leuwenhoek stated that their structure was tubular; Monro believed them to be longitudinally fibrous; Fox that they were deposited in layers; Cuvier that they are neither cellular nor fibrous, but composed of laminae; Buhat considered them analogous to rock, and fibrous; Blandin thought them to be composed of plates. The present theory of the structure of the teeth has been propounded by Retzuis, Purkinje, and others. It views the teeth as containing three different structures: ivory, enamel, and crusta petrosa. *The enamel* consists of a number of short fibres, laid parallel to each other. Under the microscope they appear to be tubular, and to have the form of six-sided prisms, with closed extremities; hence they may be viewed as elongated cells, and are supposed to be derived from the ossification of a membrane which surrounds the exterior of the tooth, as can easily be demonstrated by the action of diluted muriatic acid on the teeth. The enamel appears to remain stationary after it has formed, there being apparently no provision for its nourishment.

The ivory, or true dental substance, is formed around a cavity, in which the pulp is deposited. When a horizontal section is made of it, it is found to consist of a fibrous structure. These fibres are, however, discovered to be, by a powerful microscope, tubular. These tubes run with a slight vertical inclination from the cavity in their interior to the circumference. Sometimes these tubes divide and communicate with branching cells, all of which are filled with calcareous matter. Within the cavity, surrounded by the ivory, is placed the pulp, an organized process of the gum, from which the ivory appears to be formed by ossification. This has been proved by the gradual transition of the one into the other, the ivory being in fact ossified pulp. After the tooth has been formed it appears to undergo little change. The tubes appear to be in some respect pervious, from the ease with which they absorb coloured solutions, and this may account also for their rapid decay, when the enamel has been removed. When by disease the saliva has been rendered continually acid, the acid may, by access through these tubes, render the destruction of the teeth more rapid than before the removal of the enamel.

The human teeth in an adult amount in number to thirty-two, sixteen being placed in each jaw. These are divided into four incisors or cutting teeth, or front teeth—two canine or dog teeth—four tricuspid or smaller grinders or molars, and six grinding teeth, or larger grinders or molars. Each of these is divisible into the root, neck, and crown. The teeth of different animals vary considerably. The tusks of the elephant, being hard and compact, are called ivory. Carious teeth are tetracased teeth, on which a species of earthy matter takes place, and appears to be quite distinct from ulceration. The chemical analysis clearly points this out. A carious tooth, with a specific gravity 1·533, yielded

Cartilage,	57·78
Phosphate of lime,	30·00
Carbonate of lime,	2·09
Magnesia,	2·05
Chloride of potassium,	1·25
Moisture,	9·45

BONES.

The following table exhibits a comparative view of the chemical composition of various bony structures :—

	Bone.	Human Ivory.	Enamel.	Bony Tumour.
Cartilage,	35·93	25·38	7·84	21·12
Phosphate of lime,	51·12	54·14	76·73	65·80
Carbonate of lime,	9·77	5·76	7·67	4·84
Phosphate of magnesia,	0·63	1·37	4·09	trace.
Chlorides of potassium and sodium,	0·59	3·02	2·87	
Water,		10·37		8·72
Silica,		0·33	0·63	

The tartar of the teeth is a familiar substance. It is said to form most readily in the mouths of persons who speak much, or who hold their mouths open. It seems to be deposited from the saliva, as it contains similar ingredients. The best method of removing tartar from the teeth, or preventing its formation, is by washing the teeth every day with a brush, upon which may be placed a small quantity of very finely powdered chalk.

III.—Deglutition, or Swallowing.

The operation of mastication is a voluntary act; but the next step, or that of deglutition or swallowing, is of a different character. So soon as the food is sufficiently reduced to a pulpy state, the natural impulse seems to be to carry it by the assistance of the tongue to the back part of the mouth. This is all the voluntary exertion that is required on the part of the individual. The instant that it touches certain nerves which guard the throat, with this object in view, they are excited, and carry the impression to the spinal marrow. This impression is conveyed or reflected by a different nerve to the point of excitement, and motion is the result; this motion being the contraction of the gullet, and consequent grasping of the morsel, which is quickly conveyed by this important canal into the digestive organ, the stomach.

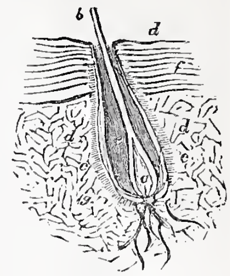
ANATOMY AND PHYSIOLOGY.

CHAPTER XXII.

ON THE FACULTY OF SENSATION AND PERCEPTION—APPENDAGES OF THE SKIN—*Continued.*

Structure and Growth of the Hairs.—The extremity of the hair, which is inserted into the skin, is contained in a sort of follicle. This *hair follicle* (in the annexed figure, *e*) is the organ which forms the hair; it is imbedded in the cellular tissue under the skin, and is prolonged to the surface of the skin by a sort of membranous canal. The *hair follicle* consists essentially of a pouch or *sac*, and a *papilla*. The membranous *pouch* or *sac*, *c*, *c*, has a narrow neck, and opens externally by a contracted opening, through which the hair, *b*, passes, without at all adhering to it. The walls of the sac are translucent. The inner surface of the sac, *c*, is smooth, not adherent to the hair, but separated from it by a reddish liquid.

Structure and Growth of Hair magnified.



e, Hair follicle.
g, Subcutaneous cellular tissue.
c, *c*, Membranous pouch or sac.
b, The hair.
a, Papilla.
f, The dermis.

From the bottom of the sac—that is, its deepest part—a *papilla* (*a*) nervous and vascular, arises: the papilla is of course fixed at the base, for here the nerves and blood-vessels enter it; but on the apex, or upper part, it is free, and this free part extends nearly to the narrow orifice above spoken of; and, as is said, in the disease called plica polonica, it extends even beyond it. Now, upon this papilla the hair is formed: first, a conical horny sheath is moulded upon the surface of the papilla, as the teeth are formed over the dental sac or follicle; on the inner side of this another and another cone succeeds, thus ultimately protruding as the hair. Into each hair follicle, one or more sebaceous follicles pour their secretions; and it is generally supposed that a very thin layer of scarf-skin lines the interior of the hair follicle.

The disorders to which the skin is liable are extremely numerous; many of them dangerous and obstinate, and some alarmingly disgusting. Leprosy, for example, and elephantiasis, the former the lepra of the Greeks and Hebrews, the latter the lepra of the Arabs, are frightful and loathsome diseases, which at one time were found over all Europe. Even yet, the lepra of the Greeks and Hebrews, or common leprosy, is by no means unfrequent, and even the elephantiasis, a frightful tubercular disease, existed very lately so far north as Shetland. The Hebrew and the Gipsy race are still subject to the common leprosy; and it is not an improbable theory, that certain skin diseases are peculiar to certain races, just as it is said that certain intestinal worms are peculiar to certain races of men. In this way, these diseases may have found their way into the northern parts of Europe about the time of the crusades, not by their being contagious, but by the progeny of intermingled races. But further observations on skin diseases would be quite misplaced in a work of this kind, the proper object of which is to submit to the reader a concise but accurate idea of the structure and functions of the organs composing his own frame chiefly.

We shall therefore conclude the history of this organ of sense, the organ of touch, with a few remarks on a disorder, not dangerous it is true, but exceedingly irksome and vexatious—we mean *corns*.

Corns are hard, horny, generally conical-shaped bodies, developed in the epidermic parts, and more especially as it would appear in the rete mucosum; they seem to grow with the apex or point of the cone inwards, the base being turned towards the scarf skin; hence, when the pressure of the shoe acts upon them, the point is forced inwards through the quick and tender true skin, which it at last pierces, thus reacting upon the subcutaneous cellular tissue. It is this no doubt which causes such excruciating pain when pressure is made over a corn. They, probably, are natural to many persons, and do not seem to have been in such individuals caused by tight shoes, or other mechanical means. During some variable seasons they are peculiarly troublesome. Their removal probably might be effected by repeated blistering and warm fomentations. The disease called bunions by many surgeons, is a dislocation of the first joint of the great toe from off the large head of the metatarsal bone supporting it. The

rounded head of this bone they mistake for a tumour; the real nature of the complaint will be fully explained in a concluding article on the form and structure of the foot in man and woman.

All the functions of the skin, and the importance of a due performance of these to the animal economy, are not as yet well understood. The care bestowed by the groom in cleansing, washing, and brushing the surface of the horse, after the severe toil of the chase or race, sufficiently proves its importance as regards the horse at least; whilst in man, if the linens or body clothes be not frequently changed, the use of the bath seems absolutely essential for the maintenance of a healthy condition. In very cold countries, as in Russia, where the perspiration is so much checked, the vapour-bath has been considered as the sole means of preserving the population from a wide-spreading and desolating scurvy; and even in otherwise temperate climates, without due exercise, and some attention at least to cleanliness, scurvy and other cutaneous disorders are apt to appear, especially if salted food be at the same time used freely. But in warm and tropical climates, where the perspiration flows freely and without effort, strong exercise is not only not necessary for the European, but may be positively hurtful to him: no European can stand strong exercise in a hot climate.

On theoretical, but by no means improbable grounds, it has been conjectured that peculiar states of the atmosphere may so check certain of the secretions of the skin as to throw them into the mass of blood, thus giving rise to symptoms resembling those produced by poisons.

An extensive loss of skin by operations, ulcers, or scalds and burns, is always productive of much inconvenience to the sufferer. On the shins or legs, for example, a trifling loss of skin by ulcer or otherwise, disqualifies the person from being received as a recruit to serve in the army; and when the loss happens to be on the face, many ingenious attempts have been made to replace it, by substituting for the lost portion another cut from a less exposed part. In this way, lips have been restored—partially at least; and a lost nose replaced by a portion of the integuments of the forehead. It is extremely probable that many such operations would succeed in very young persons, which unfortunately fail in those more advanced in years. When portions of the skin have been stripped off by violence, but still adhere partially, the surgeon ought to make every attempt, in general by replacing the integuments so removed, by a few judicious stitches and *very careful handling*, to enable the skin so injured to recover its vital connexions with the surrounding parts. There is a plastic healing force in the young, which is not found in aged persons. Surgeons to manufactories, mines, &c., cannot be too cautious in such matters.

THE SENSE OF TOUCH.

Some remarks—which, however, must be brief—on the physiology of this sense, the sense of touch, may appropriately enough close this section.

It is usual to consider the sense of touch as not confined to any particular part of the body, but extended over all. Even the internal organs are presumed to have a kind of sense of touch. This, I think, in their ordinary condition is very questionable. The sensitive nerves all over the body, whether belonging to the external integuments or not, are presumed to come from the posterior roots of the spinal nerves. But the fingers and toes in man, the extremity of the proboscis in the elephant, the tongue and lips in many animals, the nose in the pig and tepir; these are the parts fully invested with the requisite sensibility. Most headaches arise merely from the state of the external integuments of the head; still there are others, as has been proved by dissection, which have a deeper seat, thus showing that some parts of the brain are sensible whilst others are not.

Sensations, as those of touch, may arise from two sources: they may arise either from irritation applied to the nerves, or from stimuli applied to their peripheral extremities; that is to the surfaces in which they terminate, whether these be the integuments or otherwise. Thus, the horny tissue and the teeth are quite insensible, and in the healthy state so are the bones, tendons, and cartilages. When diseased, the bones become acutely sensible.

It is a curious fact, that the skin itself is not equally sensible throughout; two small bodies applied to the surface are not equally well recognised at every part as distinct from each other; the same happens in respect to temperature, and even to pressure.

The sensibility of the inner surfaces or lining membrane of the windpipe and organ of voice, is very great; that of the mouth and of the gullet less so. The lining membrane of the intestines is not particularly sensible; all which differences may and probably do depend on peculiarities in the nerves distributed to the structures respectively.

The sensation of a blow or shock may arise as well from internal as from external causes, or, in the language of metaphysics, may as well originate in a substantive affection as be occasioned by an objective reality. Thus, *feeling* is not the absolutely naked truth it is vulgarly supposed, since a body may be imagined to be felt, may be actually felt, by the person, and yet have no real existence. The sense of touch then has its delusions like the others.

The same remarks apply to the sensations of heat and cold, which are generally caused by external agencies; the burning heat and shivering cold of ague is of course entirely independent of any such agencies, arising solely from internal changes, and not remediable by any application of their opposites. A person in the cold stage of ague will continue to shiver though immersed over head in a hot bath; heat is not felt on the surface at that moment. What is called the muscular sense is a phenomenon not easily reducible to common sensation; it was first observed by Detnot De Tracy. Thus, when we raise a vessel, with the contents of which we are not acquainted, the force we employ is determined by the idea we have conceived of its weight. In descending a stair also, the probable depth of the steps is accurately guessed at or conjectured. Should a step be found much deeper than what was calculated on, the body descends very rapidly, or rather falls, and the person may receive a severe shock. When a person ignorant of the weight of quicksilver first takes up a bottle containing a considerable quantity of it, he is extremely apt to let it fall, from a miscalculation of the muscular force requisite, precisely as in descending a stair and encountering a deeper step than was expected. But if the attention be previously roused to the danger, then the muscular forces are calculated to a nicety, and with incredible rapidity; for this, however, the use of sight is absolutely requisite.

The sense of touch is subject to an illusion of an extraordinary kind, which cannot be corrected even by the sight; thus proving that the senses alone, unaided by the reasoning powers, are not to be trusted—cannot indeed be believed on all occasions. The illusion or delusion to which we allude attracted even the attention of Aristotle, so early was it observed, nor to this day has it been fully explained. It is this:—"If we place on a table, or on the palm of the hand, a marble or any other small globular body, and crossing it alternately with the fore and middle fingers,

crossed so that the marble shall only touch the outer edges or surfaces of the two fingers, the person will believe

that he touches two marbles, although he knows that only one is present." There is an expression in the above quotation to which I would particularly advert, because some continental physiologists would seem to consider the circumstance as essential in the production of the phenomenon, whereas it is not; I mean the touching the marble with the *edges* of the *fingers*. Now, any portion of the lower surface of the finger answers quite as well, and it is this which seems to have escaped the notice of the continental physiologists generally, which renders the explanation they offer of this curious illusion unsatisfactory. The explanation generally admitted is as follows:—The mind refers involuntarily all sensations experienced at different points of the body, to the position in which such points are usually placed. Now, the crossing the fingers does not prevent us feeling either of them in contact with the marble, as if they were placed naturally side by side. But in the habitual position of the fingers side by side, it is impossible that the outer edges of any two fingers be at the same time placed in sufficient contact with a single marble or other similar rounded body; and thus, when such contact actually takes place simultaneously, in respect to the two fingers, effected by the contrivance of crossing the fingers, then the mind, involuntarily believing the thing impossible, takes it for granted that two marbles, not one, must be present, and hence arises the sensation and perception of two distinct bodies. This is the explanation of the singular illusion we speak of, first offered by Condorcet, and maintained afterwards by Müller and by many others, and we believe it is very generally admitted. But there lies against this explanation the seemingly unanswerable objection, that it is not necessary to touch the marble with the *opposite edges* or margins of the two fingers; the rounded surface over the pulp suffices. There is something, then, in the crossing of the fingers which we do not understand. Another curious circumstance may be mentioned in connection with the illusion. If the middle finger be crossed over the forefinger, which is the usual mode of performing the experiment, the surface touched with the end of the middle finger will seem to us to be most remote, although in point of fact the finger is at that moment nearest to us.

Other curious phenomena have been adduced by physiologists in support of Condorcet's opinion. If by any cause whatever the lips come to be accidentally deformed, and if we then apply to them a body, a glass, for example, or cup, with whose form we are habituated, the mind will involuntarily refer the deformity to the cup or glass itself, whose curve will seem broken, thickened, or irregular. It has even been asserted that those persons who have had a new nose supplied from the skin of the forehead, to replace one lost by disease or accident, will refer any irritation produced in the new nose, not to that particular part of the body, but to the forehead from whence the new nose was taken. Such remarks require confirmation. To the same cause has been referred the pains felt in the toes by those who had long previously lost their limbs by amputation.

MATHEMATICS.

PRINCIPLES OF ALGEBRA.

Chapter VI.—Interpretation of Anomalous Solutions.

Every equation of the first degree—that is, every simple equation—may be so reduced as to have all its signs positive,* and be of the general form.

$$ax + b = cx + d.$$

* We can always change the negative terms of the equation into others which are positive, since we can always add any quantity to both members.

By subtracting $cx + b$ from each member of this equation, we get

$$ax - cx = d - b; \quad \text{whence} \quad x = \frac{d-b}{a-c}.$$

60. *Anomaly* 1.—Let it now happen that d is less than b, but a greater than c, there is then an impossible subtraction, $d - b$, in the numerator of this result. This shows that the solution is irrational; and if we examine the equation from which it is produced, we find that, on the supposition made, it is absurd: for if a be greater than c, then is ax greater than cx; and if b also be greater than d, then is $ax + b$ greater than $cx + d$, and cannot be equal to it.

This gives rise to these questions:—1. Can such an equation arise from a problem? 2. If so, is it the problem itself which is absurd, or the way of treating it? 3. If the latter, how is the method of solution to be rectified?

Problem I. *In illustration.*—In the year 1853, A's age is 40, and B's 12. Required the date at which A's age is three times that of B.

This date must either be *before* or *after* 1853; that is, either $1853 - x$, or $1853 + x$. Try the first case. Then, in $1853 - x$, A's age *was* $40 - x$, and B's *was* $12 - x$, and the condition is

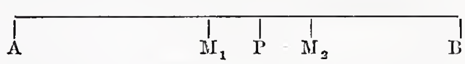
$$40 - x = 3\,(12 - x) \quad \text{whence} \quad x = \frac{36 - 40}{2}$$

which is impossible; and it is sufficiently evident that the equation is not true; for $40 - x$ must be greater than $3\,(12 - x)$ or $36 - 3x$. Now, try the second case, $1853 + x$. Then A's age *will be* $40 + x$, and B's *will be* $12 + x$, and the condition is

$$40 + x = 3\,(12 + x) \quad \text{whence} \quad x = \frac{40 - 36}{2}$$

which is possible, and gives $x = 2$, an evidently true answer; for in the year $1853 + 2$, or 1855, A's age will be 42, and B's will be 14, and $42 = 3 \times 14$. In this instance, then, the impossible subtraction arose from our assuming a date *before* instead of *after* a given epoch.

Problem II. *In illustration.*—A and B are 100 miles distant from each other, and 55 and 45 respectively from P. They start at the same instant to meet each other, and travel 10 miles and 7 miles an hour respectively. At what distance from P do they meet?



1°. Suppose that they meet at M_1; that is, let $PM_1 = x$.

Then A moves through $AM_1 = 55 - x$ in $\frac{55 - x}{10}$ hours.

And B moves through $BM_1 = 45 + x$ in $\frac{45 + x}{7}$ hours.

But A and B travel the same number of hours, therefore the equation for x is

$$\frac{55 - x}{10} = \frac{45 + x}{7} \quad \text{whence} \quad x = \frac{385 - 450}{17}$$

which is impossible, and it is otherwise evident that the equation is not true; for $\frac{55 - x}{10}$ is $= 5\frac{1}{2} - \frac{x}{10}$ and $\frac{45 + x}{7}$ is $= 6\frac{3}{7} + \frac{x}{7}$ and $5\frac{1}{2} - \frac{x}{10}$ must be less than $6\frac{3}{7} + \frac{x}{7}$ and not equal to it.

2°. Suppose that they meet at M_2; that is, let $PM_2 = x$.

Then A moves through $AM_2 = 55 + x$ in $\frac{55 + x}{10}$ hours.

And B moves through $BM_2 = 45 - x$ in $\frac{45 - x}{7}$ hours.

And these times being equal by the question, consequently

$$\frac{55 + x}{10} = \frac{45 - x}{7} \quad \text{whence} \quad x = \frac{450 - 385}{17}$$

which is possible, and gives $x = 3\frac{13}{17}$ miles. From this we conclude that the point of meeting is M_2 and not M_1; and the correctness of the solution is easily proved by verification. In this instance, then, the impossible subtraction occurred in consequence of x being taken in a direction exactly opposite to the true one.

61. Comparing the equations formed from these problems, we find

From PROBLEM I.

Incorrect, $40 - x = 3\ (12 - x)$, or $x = \dfrac{36 - 40}{2}$ years *before* 1853.

Correct, $40 + x = 3\ (12 + x)$, or $x = \dfrac{40 - 36}{2}$ years *after* 1853.

From PROBLEM II.

Incorrect, $\dfrac{55 - x}{10} = \dfrac{45 + x}{7}$, or $x = \dfrac{385 - 450}{17}$ miles *west* of P.

Correct, $\dfrac{55 + x}{10} = \dfrac{45 - x}{7}$, or $x = \dfrac{450 - 385}{17}$ miles *east* of P.

From these instances, the following principle will be understood:—

1°. When the value of x deduced from an equation, contains an impossible subtraction, the meaning of x has been misunderstood in forming that equation, and requires to be altered.

2°. The equation will be corrected by changing the sign of every term which contains x *only once as a factor.* [The rule is not extended to such terms as xx, xxx.]

3°. The result will be corrected by inverting the terms of the impossible subtraction, (that is, by changing $36 - 40$ into $40 - 36$) and giving to x a meaning directly opposite to that which was supposed when the incorrect equation was obtained.

EXAMPLE.—The state of A and B's affairs is such, that if they gain £200 and £100 respectively, A will be half as rich as B; but if they gain £700 and £200 respectively, A will be twice as rich as B. What is the actual state of their affairs?

Three cases present themselves:—1. Both parties may possess property. 2. Both may be in debt. 3. One may have property, and the other only debt.

Try the first of these suppositions, and let A's *property* be £x.

Then £$(x + 200)$ = A's property when he has gained £200.

When B has gained £100, he is twice as rich as A is after gaining £200.

$\therefore$ £$2\ (x + 200)$ = B's property when he has gained £100.

And £$2\ (x + 200)$ — £100 = £$(2x + 300)$ = B's original property.

Again: £$(x + 700)$ = A's property when he has gained £700.
£$(2\,x + 300)$ + £200 = B's property when he has gained £200.

By the question, A is now twice as rich as B; consequently,

$$\frac{x + 700}{2} = (2\,x + 300) + 200, \quad \text{whence} \quad x = \frac{700 - 1000}{3}$$

which is impossible. Try the second case, and modify the equation by 2°, and let £x be A's *debt.* This gives

$$\frac{700 - x}{2} = (300 - 2x) + 200 \qquad \text{whence} \qquad x = \frac{1000 - 700}{3}$$

and $\therefore x$ = £100. This explains A's circumstances. To find out B's, we know that when A has gained £200, his property is £$(200 - x)$; and therefore, by the question, the property of B is £$2(200 - x)$ when he has gained £100; consequently,

£100 — £$2(200 - x)$ = £$(2x - 300)$ is B's *debt* = £200 — £300
£100 + £$2(200 - x)$ = £$(300 - 2x)$ is B's *property* = £300 — £200
or £100. The answer to the question therefore is: A is in debt £100, and B has £100.

62. *Anomaly* 2.—The solution of $a\,x + b = c\,x + d$ is $x = \dfrac{d - b}{a - c}$. If it should now happen that d is greater than b, and c greater than a, there is then an impossible subtraction in the denominator of the result, and it is otherwise obvious that the equation is absurd; for c and d being greater than a and b, there is $c\,x + d$ greater than $a\,x + b$, and not equal to it. Let the sign of those terms containing x be changed; the proposed equation then becomes

$$b - a\,x = d - c\,x \qquad \text{which gives} \qquad x = \frac{d - b}{c - a}$$

and this is possible. This anomaly then resolves itself into the preceding, and the equation and result are rectified in the same way.

PROBLEM *in illustration.*—A and B, in the course of a journey between the towns of C and D, travel in the same direction; A at the rate of 9 miles an hour, and B at the rate of 7. They are, at the same moment of time, at A and B, distant 20 miles from each other. At what point between C and D are they together?

The problem does not state whether they travel towards C or D. Suppose then that they travel towards C, and are together at M_1, and let $AM_1 = x$.

Then A moves through $AM_1 = x\ \dfrac{x}{9}$ hours.

And B moves through $BM_1 = 20 + x$ in $\dfrac{20 + x}{7}$ hours.

These times are equal $\therefore\ \dfrac{x}{9} = \dfrac{20 - x}{7}$ whence $x = \dfrac{180}{7 - 9}$

which is impossible. Suppose now that they travel towards D, and let $AM_2 = x$.

Then A moves through $AM_2 = x$ in $\dfrac{x}{9}$ hours.

And B moves through $BM_2 = x - 20$ in $\dfrac{x - 20}{7}$ hours.

The times are equal $\therefore\ \dfrac{x}{9} = \dfrac{x - 20}{7}$ whence $x = \dfrac{180}{9 - 7}$

which is possible, and gives $x = 90$ miles. The answer then is: If they travel towards C, they *were* together at M_2; and if they travel towards D, they *will be* together at M_2; and M_2 is 90 miles from A's present situation, and $90 - 20$ or 70 from B's.

[It is at once obvious that $\dfrac{180}{9 - 7}$ is a correction of $\dfrac{180}{7 - 9}$, but it is not so obvious that $\dfrac{x}{9} = \dfrac{x - 20}{7}$ is a correction of $\dfrac{x}{9} = \dfrac{20 + x}{7}$. By transposition, this last becomes $\dfrac{20 + x}{7} - \dfrac{x}{9} = 0$; and changing the sign of x, we get $\dfrac{x}{9} + \dfrac{20 + x}{7} = 0$, or $\dfrac{x}{9} - \dfrac{x - 20}{7} = 0$, whence $\dfrac{x}{9} = \dfrac{x - 20}{7}$.]

Exercise.—A's age is 30, and B's 9. When *will* A be four times as old as B? *Ans.* Never; but A *was* four times as old as B two years *ago.*

63. *Anomaly* 3.—If in solving $a\ x + d = c\ x + d$, thus: $a\,x - c\,x = d - b$, or $x = \dfrac{d - b}{a - c}$, we afterwards find that a is less than c, and d less than b, it shows that in subtracting $c\,x + b$ from each side of the equation, we have subtracted too much, since by this supposition both sides are less than $c\,x + b$. Subtract then $a\,x + d$, and we get

$$b - d = c\,x - a\,x, \qquad \text{whence} \qquad x = \frac{b - d}{c - d},$$

and the subtractions are both possible. This then resolves itself into the *error of process* noticed in Art. 71, and does not arise from a misconception of the problem.

Problem.—How many gallons at 9s. must be mixed with 20 gallons at 13s., in order that the mixture may be worth 10s. a gallon?

Let $x =$ gallons at 9s., and $9x =$ their value,
Then $x + 20 =$ gallons of mixture, and $10(x + 20) =$ their value,
Also $12 \times 13 = 260 =$ the value of 20 gallons at 13s. } in shillings.

$\therefore\ 9x + 260 = 10(x + 20)$ or $10(x + 20) = 9x + 260$.

and collecting the terms containing x in the left side, we get

from the first $x = \dfrac{200 - 260}{9 - 10}$, from the second $x = \dfrac{260 - 200}{10 - 9}$

Now, as the mere disposition of the members cannot affect the truth of the equation, it follows that the impossible form of the first of those expressions can have resulted only from a faulty mode of solution. The error consists in having collected the terms containing x into the wrong side, but this error is rectified by changing the terms of the impossible subtractions, or the signs of all the terms of the equation, before dividing by the coefficient of x, (Art. 72.)

$$\therefore\ x = \frac{200 - 260}{9 - 10} = \frac{260 - 200}{10 - 9} = 60 \text{ gallons.}$$

Exercise.—How many pounds of tea at 4s. 6d. and 7s. 6d. per lb. must be mixed, to make a box of 150 lb. worth 5s. 6d. per lb.? Ans.—100 lb. at 4s. 6d. and 50 lb. at 7s. 6d.

64. *Anomaly* 4.—In solving $ax + b = cx + d$, which gives $= \dfrac{d - b}{a - c}$, if it should happen that $a = c$ or $a - c = 0$, then is

$$x = \frac{d - b}{a - c} = \frac{d - b}{0},$$

which is unintelligible, there being no answer to the question, "How often is *nothing* contained in $d - b$?" But recurring to the equation, the supposition $a = c$ gives $ax = cx$, and therefore if $ax + b = cx + d$, then must $b = d$, or otherwise the equation is absurd, and cannot be modified, as in the foregoing instances.

Problem *in Illustration.*—A and B start at a distance of 1 mile from each other, and travel towards C at the rate of a and b miles an hour respectively. In how many hours does A overtake B?

A B C

Let $x =$ the number of hours. Then the distance travelled by A is ax miles, and the distance travelled by B is bx miles. But A travels 1 mile more than B.

$$ax = bx + 1, \qquad \text{whence} \qquad x = \frac{1}{a - b},$$

which, on the supposition $a = b$ becomes $x = \dfrac{1}{0}$. This is unintelligible, and the equation impossible, being $ax = ax + 1$. But if a exceed b by any quantity, however small, then the equation and its answer are both rational. Let a be greater than b by the fraction $\frac{1}{1000000}$, then the equation becomes

$$\left(b + \frac{1}{1000000}\right) x = bx + 1, \quad \text{or} \quad bx + \frac{x}{1000000} = bx + 1,$$

which gives $x = 1000000$ hours. The same may be obtained from the first answer, for

$$x = \frac{1}{a - b} = \frac{1}{(b + \frac{1}{1000000}) - b} = \frac{1}{\frac{1}{1000000}} = 1000000^{\text{h.}}$$

Similarly: if a exceed b by $\dfrac{1}{9999999}$ then $x = 9999999^{\text{h.}}$

if a exceed b by $\dfrac{1}{9999 \ldots (n)}$ then $x = 9999 \ldots (n)^{\text{h.}}$

or the smaller the quantity is by which a exceeds b, the greater is the answer; and if $a - b$ decrease without limit, the fraction $\dfrac{1}{a - b}$ must increase without limit. This is what is meant when it is said in the language of algebra that a number is *infinite*, or that an answer is *infinitely great*, and what is denoted by the symbol ∞ or $x = \infty$.

The conclusion then is: such a result as $x = \dfrac{1}{0}$ or $x = \infty$, indicates that the supposition from which x was deduced can never hold good, or that there is no number great enough to be an answer to the problem. Nevertheless, the greater x is taken the more nearly is the equation true; for on the supposition $a = b$, the equation

$$ax = bx + 1 \text{ might be written } a = a + \frac{1}{x}$$

where it is obvious, that if x be a very great number, $\dfrac{1}{x}$ must be a very small fraction. In the problem given this does not appear to hold good, for on the supposition of A and B's rates of travelling being the same, the original distance, 1 mile, must always separate them. They can never come together unless AC becomes = BC, which never happens, since AB is always = 1 mile. But let AC = 1000000 AB, then the assumption that they have actually met, or that AB = 0 is an error which involves no more than $\frac{1}{1000000}$ of AC.

Exercise.—A reservoir has three pipes; by the first it is filled in 40 hours, and by each of the two others it is emptied in 80 hours. Now, supposing the reservoir to be half full, in what time will it be emptied when the pipes are all open, and also when $\frac{1}{9817369}$ or the supply is carried off by evaporation.

65. *Anomaly* 5.—In $ax + b = cx + d$, which gives $x = \dfrac{d - b}{a - c}$ if it should happen that $a = c$ and also $b = d$, the answer

$$\frac{d - b}{a - c} \text{ must be written } \frac{0}{0},$$

which is not intelligible. But returning to the equation, we find that, on the suppositions made, its sides are *identical*, (Art. 18,) being $ax + b = ax + b$: consequently, there is no necessity for giving x one value rather than another. This indeterminateness is shown by the symbol $\dfrac{0}{0}$.

Problem *in Illustration.*—Is there any number such, that 1 being subtracted from its product by 2, and 2 being subtracted from double the remainder, the result is equal to four times one less than the number?

Let the number be x, and the conditions are expressed by $2(2x - 1) - 2 = 4(x - 1)$, whence $x - 1 = x - 1$, which is evidently true, whatever be the value of x. The answer therefore is, that any number greater than 1 satisfies the condition of the problem; and this corresponds to the meaning given to $\dfrac{0}{0}$.

But this is not the only cause of the appearance of a fraction in the form $\dfrac{0}{0}$. Take the equation

$$(c + d)(a - b)\,x = (a + b)(a - b),$$

both members of which contain the factor $a - b$. By the rule this gives

$$x = \frac{(a + b)(a - b)}{(c + d)(a - b)} = \frac{a + b}{c + b}$$

and on the supposition $a = b$, or $a - b = 0$, this result assumes the form

$$x = \frac{0}{0} = \frac{2a}{c + d}$$

where the peculiarity $\frac{0}{0}$ is the consequence of the common factor $a - b$ becoming 0. If therefore $\frac{0}{0}$ be the result of a simple equation, it is necessary to examine whether the members of the equation involve a common factor, reducible to 0 on the particular hypothesis chosen; and if so, it must be struck out. But if no such factor exists, the symbol shows that the problem is *indeterminate.*

Exercise.—Find a number such, that 5 times two more than the number added to 3 times two less than the number, is equal to 4 times one more than double the number.

SHANKS' IMPROVED HAND-DRILL.

Fig. 1 represents in elevation the improved drill made by Mr. A. Shanks, a portion of the handle being removed to economize

Fig. 1.

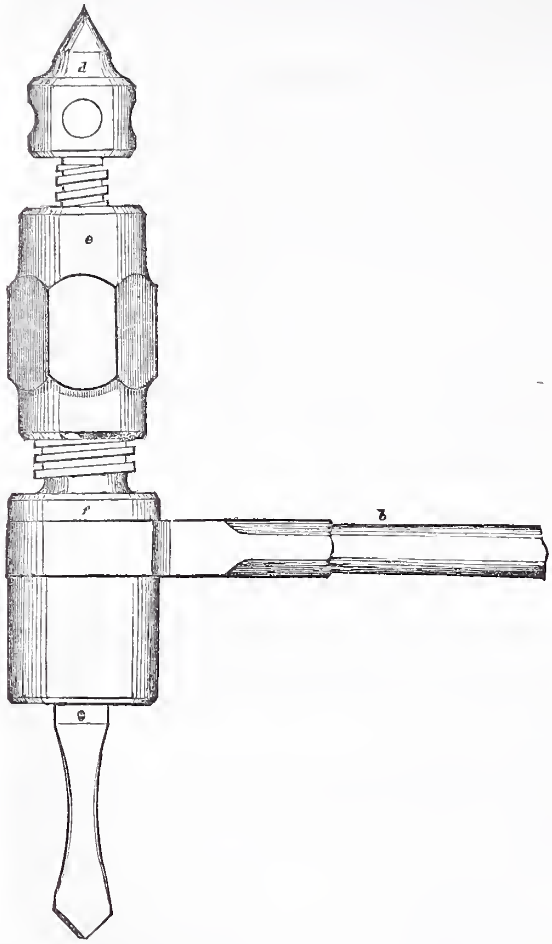
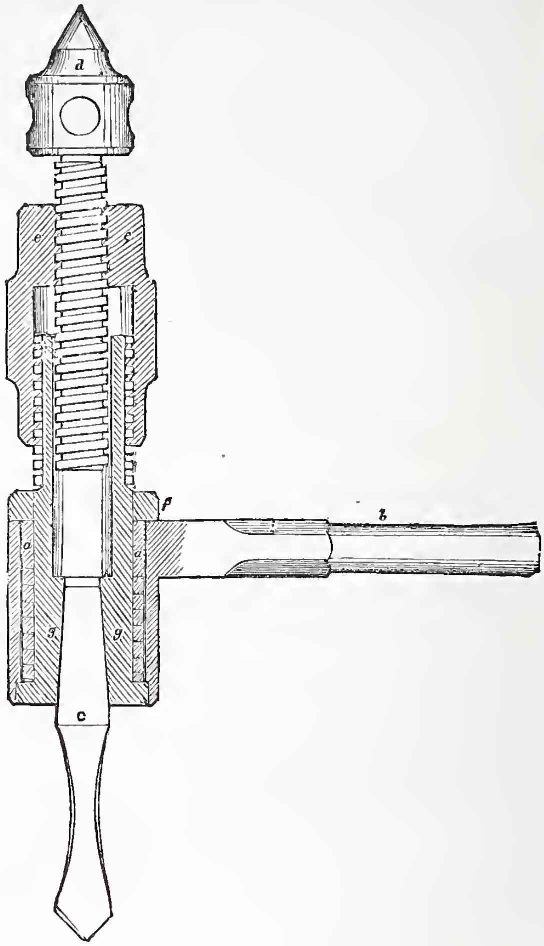
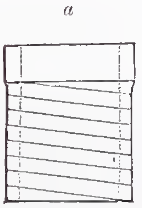


Fig. 2.



space. Fig. 2 represents the drill in section. The principal peculiarity is the spiral clutch, *a*, of which fig. 3 is a detached view. It consists of a steel riband twisted round a cylinder, and is substituted for the ratchet and detent used in ordinary hand-drills; *b* is the handle; *c*, the drill; *d*, the screw for feeding the drill while boring; *e*, the hollow nut for adjusting the drill to different lengths; *f*, a washer for holding down the handle; *g*, the drill-stock.

Fig. 3.



The clutch, being truly cylindrical inside, exactly fits the drill-stock, *g*, and rests without being fixed upon a ruff at the lower end of the stock. The whole is embraced by the socket of the handle, to the upper part of which the clutch is fixed, and the washer, *f*, keeps them in their places. The second improvement is the making of the drill-stock hollow at the upper end, to allow the screw, *d*, to pass into it; this considerably shortens the length of these parts.

When the handle is turned, with the view of turning the drill, the clutch, *a*, by its friction takes hold of the drill-stock, *g*, and turns the drill, however great the resistance may be. When the handle is returned, the clutch naturally slackens and slips upon the stock, preventing thereby the returning of the drill.

The drawing from which the above cuts were made was one-half larger than them, and represented the smallest practicable diameter and length of stock; being only one-half of the ordinary ratchet-drill, and from the small screw passing into the interior of the large one, this part is also about half the usual length.

ON THE TRANSMISSION OF POWER,

BY FORCING WATER OR OTHER DENSE FLUIDS THROUGH PIPES.

By Gilbert Lang, Mechanical Draughtsman.

The principle of this mode of transmitting power is distinguished in Hydrodynamics by the title of the *quaqua versum* pressure of fluids; the two Latin words signifying, emphatically, that fluids press in every direction.

This principle has been known to the scientific world for upwards of two centuries; but no useful application was made of it until, in 1796, Mr. Bramah took out a patent for its application in his celebrated hydrostatic press, which has become so generally useful in several arts; and indispensable more especially in compressing the loose, flocculent material, cotton, into those ponderous bales which occupy many times less bulk than the same quantity of the substance in its uncompressed state; thereby rendering it possible to transport a much greater quantity in a single ship than could be accomplished without the aid of the hydrostatic press.

Mr. Bramah was perfectly aware of the more extensive applicability of this principle of the pressure of fluids in every direc-

tion; for the specification of his patent, as given in Gregory's Mechanics, runs as follows:—"These contrivances consist in the application of water or other dense fluids to various engines, so as, in some instances, to cause them to act with immense force; in others, to communicate the motion and powers of one part of a machine to some other parts of the same machine; and lastly, to communicate the motion and force of one machine to another, where their local situations preclude the application of all other methods of connection."

It is surprising that this simple mode of communicating motion and force, has never been adopted and brought into general use, save in the solitary instance of the Hydrostatic Press. All the reasons for this it may be difficult to determine. Some people are impressed with an opinion that, although this principle is capable of accumulating immense force, the motions produced by it must necessarily be very slow; and that to render it capable of driving machinery which requires a rapid motion, it would be necessary to raise or bring up the speed by an inconvenient multiplicity of wheels and pinions, which besides would reduce the power considerably by friction; whereas nothing can be more remote from the truth. One of the chief peculiarities of this principle being the ease and simplicity with which speed can be raised or lowered to an almost indefinite extent, by merely accommodating the respective diameters of the pistons to the speed required to be produced.

Another class of individuals have indistinct, half-formed ideas relative to the supposed immense friction of water flowing through pipes. Acting on this supposition, these persons endeavour to place the force-pumps of the Hydrostatic Press in immediate juxta-position to the cylinder containing the ram, in order that there may be no loss of power from the imaginary friction of the water in the tube; and I have seen a shaft carried in a most inconvenient manner from a water-wheel to a considerable distance, for the sole purpose of working the force-pumps of a Bramah Press; which force pumps could have been wrought much more simply and effectively in the house containing the water-wheel, and the power transmitted thence to the ram through a pipe.

In short, there appears to be a doubt, an uncertainty, an ignorance on this subject, which it is the object of the present paper to remove; and the simple law, discovered by the author of this paper, which governs the transmission of power by forcing water or other dense fluids through pipes, shall be clearly pointed out, and demonstrated by deductions from the experiments of the most eminent hydraulic engineers.

Bramah's Hydrostatic Press is so well known, that there can be no occasion for an elaborate description of it. The force-pumps which bring on the prodigious pressure, have generally solid plungers of brass one inch in diameter. The ram is most frequently eight inches in diameter; but it is sometimes made as large as twelve or fourteen inches in diameter. The safety-valve shuts with its conical point a tube one-eighth of an inch in diameter, and the lever of this valve is loaded with a weight equivalent to ·168 lbs. of direct pressure on the valve; that is to say, 168 lbs. of pressure upon a circle one eighth of an inch in diameter. The force-pumps are wrought until this enormous pressure is actually overcome, and the valve lifted. There is then, by the law of the *quaqua versum* pressure of fluids, a pressure of 168 lbs. exerted on as many circles one-eighth of an inch diameter as are equal to the whole area of the surfaces in contact with the water. The plungers of the force-pumps being one inch in diameter, and the areas of circles being to one another as the squares of their diameters, the amount of pressure on the cross section of the plungers is sixty-four times that exerted on the valve. Consequently, the pressure upon the area of a circle only one inch in diameter, is no less than 10752 lbs., or 4 tons 16 cwt.; compared with which, the highest degree of pressure made use of in steam-engines is insignificant. For the same reasons, namely, that the areas of circles are to one another as the squares of their diameters, and that the pressures are in direct proportion to the areas, the amount of pressure exerted to thrust out a ram of eight inches in diameter, is equal to 307 tons. And if the ram were 12 inches in diameter, the pressure exerted on its cross section would be equal to 691 tons. Assuming the mean height of the barometer to be 30 inches, the enormous pressure made use of in the Bramah Press is equal to 932 atmospheres. It is also equal to the pressure of a column of water 31,632 feet of perpendicular altitude; which is nearly equal to the height of the loftiest mountain on the surface of the globe.

Now, the power does not reside in the Hydrostatic Press; it is not inherent in it; but appertains to the men by whom, or to the engine by which, the force-pumps are wrought; and is transmitted through the medium of the water to the ram. Hence the power of the ram is the same as that of the force-pump although the one is eight inches in diameter, and the other only one inch; although the former can lift a weight or overcome a resistance equal to 307 tons, while the latter can only overcome a resistance or lift a weight equal to 4 tons 16 cwt. The reason of this is, that the velocity of the piston of the force-pump is just as many times greater than the velocity of the ram, as the weight capable of being raised by the ram exceeds the weight capable of being raised by the piston of the force-pump; the weights are as the areas directly, the velocities as the areas inversely.

I have stated that the pressure upon a circle one inch in diameter is equal to 10,752 lbs.; I have stated this because it is what is generally used, and I like to deal with facts, not theories; but, to avoid fractions in my subsequent calculations, I will suppose the pressure upon a circle one inch in diameter to be 11000 lbs., which would be produced by adding 4 lbs. to the pressure on the safety-valve. Then if the ram be 10 inches in diameter, the weight it would be capable of raising would be 1100000 lbs. Now if the velocity imparted to the plungers of the force pumps be 300 feet per minute, the ram would rise onl· three feet in the same time. But 11000 lbs. with a velocity of 300 feet per minute, are equal to 1100000 lbs. with a velocity of three feet per minute. If we assume the measure of a horse power to be 33000 lbs. raised with a velocity of one foot per minute, then the force-pumps, to produce the effect mentioned in the preceding example, would require to be wrought by an engine of 100 horse power; and the power of that engine would be transmitted through the medium of the water to the ram.

This is an example in which a rapid motion is converted into a very slow motion, but capable of raising a great weight, or of overcoming an immense resistance. The converse of this example holds equally good; the force-pumps may be constructed of large diameter, and the ram or piston to which the motion is to be communicated may be of small diameter, and their velocities, as before stated, will be inversely as the areas of their cross sections, or as the squares of their diameters.

It does not belong to my present object to show how the rectilinear motion of the pistons may be converted into the reciprocating and rotatory motions. I leave it to the intelligent mechanic who adopts this mode of transmitting power, to make use of that method which his experience recommends as best adapted to suit the particular object he may have in view. My object is to point out the law which I have discovered, which regulates the transmission of power through pipes filled with water or other non-elastic fluids; and to shew that in attending to this law, large quantities of power may be transmitted through pipes of comparatively small diameter, and with immaterial loss from the friction or adhesion of the water in the pipes; but that by neglecting this law, the quantities of power capable of being transmitted through pipes will be small, and the loss from friction proportionably great.

The law which I have to announce is, that the quantities of power capable of being transmitted through a given pipe, the absolute loss from friction remaining the same, are directly as the pressures. That is to say, if through a given pipe, at any particular pressure, 10 horse power can be transmitted with a loss from friction of 1 horse power, then, by increasing the pressure ten times, 100 horse power could be transmitted through the same pipe, and the loss from friction would be still 1 horse power. And if the pressure be increased 100 times what it was in the first instance, then 1000 horse power could be transmitted by the same pipe, and the loss by friction would still be 1 horse power. This has no reference to the relative strengths of the pipes; it being obvious that when the pressure is considerably increased, the pipes must be made stronger to bear it. The additional thickness required in the metal of the pipes to withstand a high pressure, cannot be attended with any inconvenience in practice; for to withstand the enormous pressure daily employed in the hydrostatic press, cylinders of cast-iron require to have the thickness of the metal

of which they are made only one-half of their internal diameter or bore.

For example, cast-iron pipes of 4 inches diameter, would require their metal 2 inches thick. Now, a pipe of 4 inches diameter is as large as is likely to be employed in this mode of transmitting power; for a pipe of this diameter, with a pressure equal to that of the Hydrostatic Press, is capable of transmitting several hundred horse power to a distance of many thousand feet, in fact to a distance of several miles, and with so trifling a comparative loss of power, that it may be disregarded.

I will make this plainly appear. Experiments were made upon one of the pipes by which the city of Edinburgh is or was supplied with water. The length of this pipe was 14,930 feet, its diameter being $4\frac{1}{2}$ inches, and the slope of the pipe to the point of delivery, or in other words the head of water, 51 feet. The actual discharge of this pipe at its maximum was found to be 11·333 cubic feet per minute. The velocity with which the water flows through the pipe, in order to produce this discharge, will be found to be 103 feet per minute. The pressure is 22 lbs. on the square inch; and the area of the cross section of a pipe $4\frac{1}{2}$ inches in diameter is 15·9 square inches; from which data it will appear that the power possessed by the water, after having passed through the pipe, is $1\frac{1}{11}$, or little more than one horse power.

Now, to those who are acquainted with hydraulics, it is an easy matter to compute what the discharge would have been independent of the friction of the water in the pipe; in other words, what the discharge would have been through a short cylindric tube $4\frac{1}{2}$ inches in diameter, with a head of water of 51 feet. Instead of 11·333 cubic feet per minute, it would have been 27 times this quantity, or 306 cubic feet per minute; and the amount of power would have been $29\frac{1}{2}$ horse power. So that the friction of the water in passing through the pipe has actually robbed it of $28\frac{1}{2}$ horse power, and there remains only one horse power effective.*

It appears then that if there had been a wish to have made use of the power arising from the natural pressure of the water, although there was $29\frac{1}{2}$ horse power at the head or source, yet $28\frac{1}{2}$ was expended on friction and lost, and only one horse power remained available at the terminus of the pipe. I insist upon this point, because I wish to make it apparent that it is not advantageous to attempt to make use of the natural weight or pressure of water for originating power, by conducting it through a pipe to a distance from its source, because a very considerable proportion of the power will be expended on friction. The water-wheel or water-mill should be erected as near to the source of power as possible; and the power should be conducted to the spot where it is desired to render it available, by forcing water through a pipe at a very high pressure; under which conditions, the loss of power from friction will be the least.

Let us now ascertain what amount of power could be transmitted by the pipe in the preceding example, at the high pressure employed in the Hydrostatic Press; the discharge of water per minute remaining the same, namely $11\frac{1}{3}$ cubic feet, which, it will be remembered, it requires $28\frac{1}{2}$ horse power to produce. If we employ an engine of 100 horse power to work alternately two force-pumps, the area of the pistons of each of which is 3 circular inches; and let the pressure upon each circular inch be 11,000 lbs.; the pressure upon each of the pistons will then be 33,000 lbs., and they will move with a velocity of 100 feet per minute. If the pipe through which the water is forced have the same area, namely 3 circular inches, which is about $1\frac{3}{4}$ inches in diameter; then the water would flow through the pipe with a velocity of 100 feet per minute, which would give a discharge of 1·636 cubic feet per minute. But the $4\frac{1}{2}$-inch pipe gave a discharge of 11·333 cubic feet per minute. Therefore, as many times as 1·636 is contained in 11·333, so many hundred horse power could be transmitted by the above pipe. This amount will be found to be 690 horse power; and it was already shown that it took $28\frac{1}{2}$ horse power to force the water through the pipe, which is $\frac{1}{24}$th of the whole amount, or about 4 per cent. Therefore it has been shown that 690 horse power could be transmitted to a distance of 14,930 feet, which is upwards of $2\frac{3}{4}$ miles, by a cast-iron pipe $4\frac{1}{2}$ inches in diameter, and that the loss from friction would be only 4 per cent.

* Rather, the resistance in the pipe to the passage of the water through it, prevented $28\frac{1}{2}$ H. P. from being expended—ED.

I will give another example from the following table of the mean results of the experiments of M. Couplet on the discharge of water through long tubes :—

No. of Experiment.	Length of Tube, in toises	Diam. of Tube, in inches	POSITION, &c., OF TUBE.	Height of the Head of Water. ft.	in.	Ratio of the Effective Discharge to the Discharge independent of Friction
1			Iron, with various bendings, both horizontal and vertical,	0	9	$\frac{1}{28.5}$
2	297	4		1	9	$\frac{1}{26.53}$
3				2	7	$\frac{1}{25.79}$
4	285	6	Iron, with various bendings, both horizontal & vertical,	3	0	$\frac{1}{12.35}$
5				5	3	$\frac{1}{11.37}$
6			Partly stone and partly metal, with various bendings, both horizontal and vertical,	0	$5\frac{1}{12}$	$\frac{1}{23.1}$
7				0	$11\frac{1}{3}$	$\frac{1}{20.98}$
8	1170	5		1	$4\frac{3}{4}$	$\frac{1}{19.49}$
9				1	$9\frac{1}{12}$	$\frac{1}{18.78}$
10				2	1	$\frac{1}{16.46}$
11	600	12	Iron with various bendings, &c.	12	$1\frac{1}{4}$	$\frac{1}{10.08}$
12	600	18	Do. do.	12	$1\frac{1}{4}$	$\frac{1}{6.05}$
13	790	18	Do. do.	4	$7\frac{1}{2}$	$\frac{1}{10.11}$
14	2340	12	Do. do.	20	3	$\frac{1}{19.34}$

The measures in this table being French, it is necessary to reduce them to English; for which purpose say, as 1 : 1·06578 : : F : E.

I will take the last experiment in the table, No. 14, because the length of the pipe mentioned in it is nearly the same as that of the pipe in the preceding example, while it affords a contrast from its greater diameter. The length of this pipe is 2340 toises or fathoms, equivalent to 14963 feet English; its diameter is 12 inches French, equal to $12\frac{3}{4}$ inches English; and the head of water is 20 feet 3 inches French, equal to 21 feet 7 inches English. Under these conditions, the discharge was $\frac{1}{19.34}$th part of what would have taken place independent of friction; or, in other words, through a short cylindric tube with the same head of water. Those who are familiar with hydraulics can easily ascertain what this discharge would have been. The formula I employ is $Q = 5{\cdot}1086\, d^2\, T \sqrt{H}$; where Q denotes the quantity in cubic feet, d the diameter in feet, T the time in seconds, and H the height of the head of water in feet. The formula and the table are both taken from the Article on "Hydrodynamics" in the Encyclopedia Metropolitana, by Professor Barlow.

Making use of the above formula, therefore, the discharge, independent of friction, will be found to be 1615·5 cubic feet per minute; and the discharge from the pipe, 14963 feet in length, being $\frac{1}{19.34}$th of this, it is consequently 83·7 cubic feet per minute. The velocity of the water in the first instance would have been 1811 feet per minute, and in the latter was 93·8 feet per minute. The pressure on a square inch, resulting from a column of water 21 feet 7 inches in perpendicular height, is 9·33 lbs.; and the number of square inches in the area of a pipe 12·75 inches in diameter, is 128.

Computing from these data, the amount of power possessed by the water, independent of friction, is 65·8 horse power; and at the terminus of the pipe not quite $3\frac{1}{2}$ horse power; showing that upwards of 62 horse power has been expended in overcoming the friction or adhesion of the water, and forcing it through the pipe.

This affords an additional instance of the disadvantage of endeavouring to employ the natural pressure of water for motive purposes at a distance from its source, as nearly the whole power is expended, both in this and the preceding example, in overcoming the friction.

It will be said that 62 horse power is a great expenditure on friction; but in the first place consider the distance, 14963 feet, or very nearly three miles; and in the next place let us ascertain what amount of power could be transmitted by a pipe of $12\frac{3}{4}$ inches diameter to that distance, at the pressure of 11000 lbs. on a circular inch, the loss from friction remaining the same, namely 62 horse power.

I have already shown that at that pressure 1·636 cubic feet of water is expended per minute in transmitting 100 horse power; and the discharge from the pipe in the example before

us having been found to be 93·8 cubic feet per minute, consequently, as many times as 1·636 is contained in 93·8, so many hundred horse power can be transmitted by the pipe. It will be found that 5,116 is the result; and it was stated previously, that the loss from friction was 62 horse power; which is $\frac{1}{83}$d part of the whole, or a little more than one per cent.

Thus it has been shown, that 5,116 horse power can be transmitted to a distance of $2\frac{3}{4}$ miles by a pipe $12\frac{3}{4}$ inches internal diameter, and with a loss from the friction of the water of only 1 per cent.

It would not be advantageous, however, to make use of a pipe of $12\frac{3}{4}$ inches in diameter to transmit the above quantity of power, because, to withstand the pressure, the metal would require to be 6 inches thick. A much smaller pipe would transmit 5,000 horse power to the distance of $2\frac{3}{4}$ miles, allowing a greater per centage from loss for friction.

But it is not probable that there will speedily be occasion for transmitting such a vast amount of power from one single source; although it is impossible for us to foretell what extraordinary things may take place, judging from the wonderful advances of the arts in our times. When engines of 1000 horse power are placed on board of vessels for the purpose of propelling them across the ocean, who can affirm that the tremendous amount of power possessed by many water-falls may not be forced to contribute a trifling proportion to the wants of man? and trifling, indeed, would be the proportion, although 5000 horse power were withdrawn for the uses of the arts from the cataract of Niagara!

But none of the streams with which we are familiar present this awful sublimity of power; yet many are capable of supplying five or six hundred horse power. Now, the pipe in the preceding example, at a tenth-part of the pressure, and of corresponding reduction in strength, would transmit 511 horse power, the loss from friction remaining the same, or 62 horse power; and this to a distance of $2\frac{3}{4}$ miles, a distance to which no engineer would propose to transmit power by shafts. Then, arrived at that distance, the power may be employed directly at any speed which may be desired, by simply proportioning the diameter of a piston; or it may be distributed into a thousand channels, by the simplest and least expensive means. Surely I have said enough to excite an interest, and cause at least inquiry to be made into the capabilities of this mode of transmitting power.

But it may be said, the examples I have given are for greater distances than it is usual to conduct power. I will therefore give one other example, in which the distance is not so great.

I will select the third experiment in the table, in which a pipe of 297 toises in length, and 4 inches diameter, with a head of water of 2 feet 7 inches, was employed. These measures, reduced to corresponding English, are, 633 yards in length, $4\frac{1}{4}$ inches diameter of pipe, and 2 feet 9 inches the head of water. Employing the same formula as in the preceding examples, I find that the discharge of water per minute, through a short cylindric tube of the above diameter, is 64 cubic feet, which gives a velocity of 648 feet per minute. Now, the pressure of a column of water 2 feet 9 inches in height is 1·18 lb. on the square inch; and the number of square inches in the section of a pipe $4\frac{1}{4}$ inches diameter is 14. From which data it will be seen that the whole force of the water is scarcely $\frac{1}{3}$d of a horse power.

I have said the discharge through a short cylindric tube is 64 cubic feet per minute; and by referring to the table, it will be seen that the discharge through the pipe 297 toises or 633 yards in length, was $\frac{1}{25\cdot79}$th part of this; which is 2·48 cubic feet per minute. Now, it was formerly shown that 1·636 cubic feet was expended per minute in transmitting 100 horse power at the pressure of 11000 lbs. on a circular inch. Therefore, as many times as 1.636 is contained in 2·48, so many hundred horse power can be transmitted by the above pipe. It will be found on computation to be 150, and it was shown that the force required to propel the water through the tube was scarcely $\frac{1}{3}$d of a horse power. Therefore it is shown that 150 horse power can be transmitted through a pipe $4\frac{1}{4}$ inches in diameter, to a distance of 633 yards; and that the loss from the friction of the water is only $\frac{1}{3}$d of a horse power.

By sacrificing a little more of the power, say five or six horse power, it is clear, from the above example, that several hundred horse power could be transmitted by a pipe of $4\frac{1}{4}$ inches in diameter, to a distance of 500 or 600 yards.

The few examples I have given will serve to introduce the subject to the notice of the public. Those who feel interested may make additional calculations, either from the table which I have furnished, or by computing the discharge for any assigned diameter and length of tube with any given head of water; the rules for which they will find in any good treatise on hydrodynamics.

I will meanwhile institute a short comparison between the hydraulic mode of transmitting power and the mechanical method at present in use.

The ordinary mode of transmitting power is by shafts, to which the power is communicated, and from which it is taken by means of cranks, toothed wheels, pulleys, and belts, and a variety of other contrivances. But this method, though the most convenient under ordinary circumstances, possesses disadvantages which the method of transmitting power that I have described in the preceding pages does not possess; and which, consequently, gives the latter, under certain circumstances, a vast superiority over the former.

In the first place, shafts are attended with a considerable degree of friction at their journals, whereby a serious loss of power is occasioned. Indeed the loss of power from this cause is so great, that if the shaft be prolonged to a certain distance, the whole amount of power would be consumed solely in driving the shaft. This sets a limit, and not a very remote one, to the distance to which power can be transmitted by shafts. But it has been shown, in the course of this essay, that by forcing water through pipes, power may be transmitted to a distance absolutely vast in comparison; and that the loss of power arising from the friction of the water is so trifling, that it may be nearly disregarded.

The second defect which the method of transmitting power by shafts labours under, arises from the inflexibility of shafting. Wherever the shaft requires to turn an angle, and at every point where power requires to be given off, mitre or bevel wheels must be employed, which occasion an additional loss of power from friction, whereby also a limit is set to the degree of distribution by which power can be carried by this means. Contrast with this the flexibility of a pipe, and the ease with which power can be distributed by its simple agency, by means of branches and ramifications.

A third point in which the mechanical mode of transmitting power bears an inferiority to the hydraulic method, is in reference to economy. At the cotton manufactory at Catrine, in Ayrshire, the power of the water-wheels is said to be transmitted to the distance of two hundred yards, by a cast-iron shaft of 14 inches diameter. These water-wheels are said to possess 220 horse power; but in all probability they are overrated.

At Deanston cotton works, Perthshire, the power is transmitted from the water-wheels by a cast-iron shaft, which for about 50 yards is $13\frac{3}{4}$ inches diameter, and for about 100 yards afterwards is 10 inches diameter. The power of the water-wheels at Deanston, is affirmed to amount to 360 horse power; but in reality they do not exceed the half of this. At certain points where these shafts form an angle, each pair of mitre wheels weighs upwards of three tons.

What the precise loss of power is, arising from the friction of these ponderous shafts, I am unable to state; though it is acknowledged to be great.

This, however, is not the point to which I wish at present to direct attention; but the cost of these enormous masses of cast iron, with their pillow-blocks and bushes, and the huge masses of stone on which the pillow-blocks are bedded. Neither is this the entire expense; for these large shafts are carried underground through regularly constructed tunnels, large enough to permit a man to pass through for the purpose of oiling their journals.

Now, from the experiments which I have detailed in the course of this article, it must appear evident that a cast-iron pipe of 2 or 3 inches internal diameter, the metal of which, to withstand the pressure, need not exceed $1\frac{1}{2}$ inch in thickness, would transmit the whole power in either of the above cases, with a very trifling diminution from friction.

The difference between the weight and cost of material by these two methods, and the facility with which bends can be made, and the power distributed by the hydraulic method, are here the points of contrast. Add to this, that no expensive tunnel is necessary for containing the pipes. They require

simply to be laid in the earth beyond the reach of frost, against the effects of which a depth of eighteen inches is sufficient to protect them.

But there are cases in which shafting cannot at all compete with the hydraulic mode of transmitting power. There is an immense water power distributed over the country, but frequently occurring in situations sufficiently near to which to admit of a shaft being employed to transmit the power, it is not convenient, or perhaps not possible to erect a factory or other building for holding the machinery to which it is desired to apply the power. But by erecting a water-wheel at the fall, or what will frequently in such situations be found more applicable, one of Whitelaw and Stirrat's improved water-mills; and employing either to force water through a pipe, the power may in this manner be transmitted to a distance of many hundred yards; or if required, to a distance of several miles, and with trifling loss, or even with a slight accession of power, if the pipe is carried down a declivity, to the situation where it may be convenient to establish the works and apply the power.

For instance, a magnificent fall of water may occur in a narrow rocky glen in some of our mountainous districts, and at the distance of a few miles from a bay, on the shores of which there may be sufficient level ground for the erection of a village and of a cotton factory. Now, instead of building the factory in an inconvenient situation in the vicinity of the waterfall, and constructing a cart-road at great expense through the glen, by which the heavy bales of cotton would be transported up a toilsome ascent, and the produce of the factory would be returned to the harbour;—instead of these inconveniences, let the factory be built adjacent to the harbour, and let the power be transmitted by the simple agency of a pipe from the water-wheel or mill erected at the distant water-fall. There may also, in the descent of the glen, occur a succession of falls; and each may be forced to contribute its quota of power, by a branch to the pipe passing down the glen.

Analogous instances in which this method of transmitting power may be applied, will readily suggest themselves to the reader. Mines frequently are situated in mountainous districts; and although water power may not occur in such close proximity to the mine, as to render it available by means of shafting, either for pumping water, or raising the ore; yet now I have pointed out the means by which the expensive services of the steam-engine may in many instances be superseded, and the cheaper services of water employed in its stead. Nor is this all; for I have proposed to employ the facilities held out by this mode of transmitting power, in another field; namely, for the purpose of alleviating human labour in mines, by performing the more laborious operations of mining by machinery; whereby not only shall man be saved the task of performing the more fatiguing and dangerous portions of the labour, but also the produce of mines shall be rendered more abundant and cheaper, reflecting endless advantage on the arts which minister to the comfort of man. Neither let the miner be dispirited on account of the invasion of his ancient domain by all-subduing machinery; for where one man is freed from his dangerous and disgusting toil, ten men will be employed in the lighter task of removing the materials wrought by the unfeeling, untiring machine.

Also, I have not confined myself merely to the task of investigating the laws of this mode of transmitting power, nor of overcoming the practical difficulties of joints, and valves, and pistons, which I may affirm I have overcome; but I have also addressed myself to the endeavour of contriving machinery to perform the more laborious operations of mining, and principally in the working of coal; which, from its comparatively soft nature, is more susceptible of being wrought by machinery than stone, or some of the harder minerals; yet, what more distressing than to behold the miserable collier lying upon his side, and, with his pickaxe, undermining slowly and painfully the overhanging mass, which threatens every instant to fall, and frequently does fall, and crush him!

This mode of transmitting power might also be employed as a powerful auxiliary in extinguishing fires. Pipes for transmitting power might be laid down in large towns, along with the pipes for supplying the town with water; and an engine connected with these pipes, which, when its services were not otherwise required, might be employed in raising water. Portable fire-engines might also be constructed, not to be wrought by manual labour, but to be connected with the pipes through which the power is transmitted; so that the power of the engine might be rendered available at any point where a fire might break out. Then, if a copious supply of water were furnished, instead of the power of twenty or thirty men, awkwardly applied, an engine of twenty-five, fifty, or a hundred horse-power might be employed in throwing a deluge of water on the burning buildings.

When railways cross a mountainous tract of country, in which case stationary engines may be required to work inclines, instead of erecting steam-engines, advantage may be taken of some of the numerous waterfalls with which mountainous districts abound, and the power may be transmitted by the means I have described.

ON THE DISLOCATIONS OF THE STRATA IN THE COAL-FIELDS OF SCOTLAND.

By James Robertson, Esq., Mining Engineer, Edinburgh.

The subject of Dislocations forms a very important branch of the art of mining; and it is to an imperfect acquaintance with this department, on the part of practical men, that many of the disappointments attending mining speculations must be attributed. It is hoped, therefore, that the present attempt to imbody the facts attending the appearance of dislocations in the Scottish coal-fields, will be viewed with indulgence by the scientific geologist.

It is perhaps unnecessary, at the present day, to remark, that the rocks composing the crust of the earth are associated together in such a manner as to admit of classification; and that it is the general law of sequence and alternation developed in their arrangement, which guides the miner in his search for the mineral substances which are useful to man.

On passing through the loose soil and decayed vegetable matter which is spread over the surface, we find layers of clay, sand, and gravel; and beneath these, different kinds of hard rocks, alternating in regular succession to the greatest depth to which man has yet had an opportunity of observing. The regularity of these stratified rocks is, however, often suddenly interrupted by abrupt fractures or dislocations, or by the interposition of another description of rocks, which alter the original levels, or cut across and otherwise derange the continuity of the first. This class has received the name of igneous rocks, from the supposition that they have been ejected from below in a state of fusion, above and amongst the more regular stratified or sedimentary formations.

From a similarity of composition, or an apparent order of superposition, all rocks have been grouped into several great classes, composed of many subordinate members, and it is to one of these classes that our attention will now be particularly directed.

The Coal Formation.—This important formation consists of alternating strata of coal, shale, and sandstone, with subordinate beds of limestone, fire-clay, and argillaceous ironstone; these alternations being frequently and indefinitely repeated.

The coal formation rests upon the mountain limestone, and in a tabular view is immediately covered by the magnesian limestone, or new red sandstone group of rocks. In Scotland, the coal formation is seldom found covered by any of the upper series of rocks, but appears to have been denuded of these at some early period of the earth's history, and now lies in partial basins, capped only by the alluvial cover; and it is under this aspect that it will now be considered in connection with our subject.

A coal-field, in its most simple form, or when undisturbed and perfectly free from dislocations, may be considered to consist of a series of strata lying in regular succession over each other, and in their arrangement resembling a rude-shaped basin or trough, of greater or less extent, filled up with layers of the different substances forming the coal measures; each layer, like the edge of a saucer, cropping out or coming to the surface in succession all round.

Fig. 1.

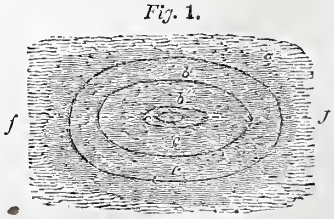
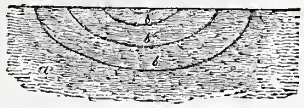


Fig. 1 is a plan of a coal-field in its simplest form; and fig. 2 is a section of the same through the dotted line f, f; a, a, is the fundamental rock, over which the coal measures have been deposited; b', b'', &c., the different

seams of coal cropping out to the surface; *c, c,* the intermediate strata conformably stratified to the beds of coal, and also cropping out to the surface through the alluvial cover.

Fig. 2.



The outline of a regular basin of this description, in a nearly level tract of country, as shown by the outburst of the lowest coal, would be of a circular or oval form; but if the surface of the ground be intersected by deep vallies, and traversed by ranges of hills, the outline will then be more irregular.

Fig. 3.

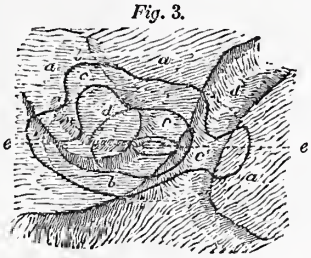
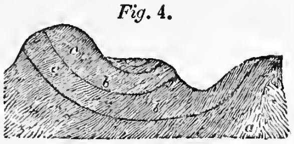


Fig. 3 is a plan of a regular basin, showing the apparently irregular outline of the outbursts of the coals, as altered by the uneven nature of the surface. *a, a,* is the fundamental rock; *b, b,* the seams of coal; *c, c,* the concomitant strata. The dotted lines, *d, d,* represent the more regular appearance which the outbursts of the seams of coal would have assumed had the ground been on the same level as *e e* throughout; and the full black lines show the deviation produced by the irregularity of the surface; the high ground throwing the outburst farther from the centre of the basin, and the valleys bringing them farther in. Fig. 4 is a section of the same basin, through the dotted line *e, e,* having the same letters of reference as fig. 3.

Fig. 4.



From the preceding remarks, it appears that a coal-field might be of a perfectly regular basin shape, and undisturbed by dislocations; while at the same time the outburst of each stratum may present the most dissimilar and distorted outline; so that considerable care is required, while investigating a coal-field, to ascertain whether an irregularity of outline in the crop of any particular coal be not entirely attributable to the irregular nature of the surface of the ground.

Coal-fields are, however, rarely found to assume a perfect basin shape; on the contrary, they are generally divided into various compartments, or rather broken into distinct fragments, by numerous dislocations of the strata, which separate and tilt up, or depress the various beds of coal and accompanying rocks, and distribute them in new positions, often in such an extraordinary manner that all trace of their original arrangement is destroyed, although there is little doubt that the various disjoined parts formed originally one or more great basins.

Having in these remarks given a general sketch of the nature of coal measures, the disturbances by which the basins are so frequently damaged will now be more particularly considered.

Dislocations.—Dislocation is a general term, implying a fracture or sudden break in the strata, whereby the continuity of any particular bed is destroyed, and a displacement or alteration of level takes place; or, instead of continuing in its original course, is abruptly lifted up or thrown down to a greater or less distance. When these shifts, or fissures of division, are of considerable width, and filled up with extraneous substances, they are then termed dykes—the nature of which will not now be considered—our attention being at present directed to the subject of dislocations only, and these will now be noticed in relation to their length, depth, width, dip, extent of heave, intersections, contents, the changes produced by them on the adjacent strata, and their effects on a coal-field—avoiding as much as possible any theoretic views regarding their origin.

Direction of Dislocations.—Very little is yet known on this point, but we are led to anticipate that a careful investigation of this subject would be rewarded by the discovery of some general law. It is only known at present that the great and leading dislocations of a coal-field, stretch in an easterly and westerly direction more frequently than in any other; but we are still ignorant in how far their run is governed by the original form of the basins, or if it be in any way connected with the ranges of igneous rocks, with which the strata of a coal field are always more or less surrounded or entangled. Probably the synclinal line of the fundamental rocks, over which the carboniferous strata have been deposited, or the anticlinal axis which they may have subsequently assumed, may have an influence on the direction of these fractures. In the absence, then, of a general law, we find, in a practical point of view, that the dislocations of a coal field run in almost every direction, either branching out on both sides forming a principal fracture, or meeting and running into each other in every possible angle; and it is, perhaps, unnecessary to state, that from this circumstance no relation can exist between the direction of the fissures and the dip and rise of the strata which they traverse, although it is no doubt generally observed that the more important dislocations run across the strata in a direction from dip to rise.

Though dislocations never continue for any distance in a perfectly straight line, but are generally found to follow an irregular curved or gently bent direction, yet, in an extended view, they present an approximation to a leading line in some particular direction, never turning entirely round, or ever abruptly leading from the general direction of their course.

Fig. 5.

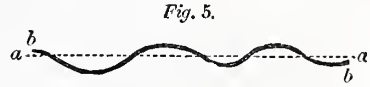


Fig. 5 is a plan of a district traversed by a dislocation. The dotted line *a a* shows the general course of the fracture; *b b* is the fracture itself, maintaining in its general run a decided approximation to the line *a a.*

The above remarks apply equally to the perpendicular run of dislocations, but this will be noticed more particularly under the head of dip and rise of dislocations.

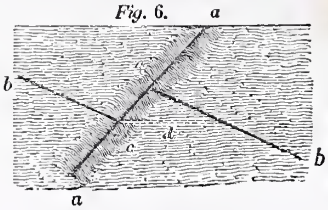
Length of Dislocations.—On this subject we are also much in the dark—as it is yet to be learned if the dislocations of the coal measures are connected with the surrounding groups of rocks, or are entirely independent of these. We know that dislocations often extend to a great distance without any symptoms of diminution—cutting across every seam of coal met with in the district; but as the attention of the miner is solely directed to the workable seams of coal, ironstone, and limestone, of a coal-field, the dislocations have not been traced farther than these; and it is consequently yet unknown whether they ever continue their course into and across the surrounding rocks which enclose the coal measures. It is well known, also, that dislocations are frequently of a very limited extent—appearing imperceptibly, and gradually dividing the strata, being accompanied by a heave of varying magnitude, and then as gradually running out to nothing, and entirely disappearing in a very short distance.

Depth of Dislocations.—The observations just made in reference to length, will also apply to the depth of dislocations, as they have never been traced to the deeper seated rocks, nor followed in their course upwards to the overlying formations. It has also been frequently observed, that inconsiderable dislocations in a seam of coal tail out, or become imperceptible, in the seams immediately above and beneath.

Width of Dislocations.—A dislocation being a mere crack and displacement of the strata, cannot be considered, properly speaking, as possessing substance or width; but it is generally found, that instead of the severed parts again adhering closely in their new position, that a sheet of extraneous matter is interposed. This substance is usually clay, either pure, or mixed with fragments of the ruptured strata, and varying from the smallest possible thickness to a width of several feet. It is not unusual also to find the fissures filled up with sand, gravel, and even hard rock; but in this last case, the dislocation more properly comes under the denomination of a dyke; and it may be observed in passing, that the rocks which constitute a dyke, geologically speaking, are all of igneous origin. The miners, from the habit of calling all dislocations dykes, and of erroneously considering them as substances, and not mere accidents or breaks, may mislead the unpractised observer; as not being satisfied with the sheet of clay forming what they erroneously term a dyke, they include the shattered strata on both sides under this name; and even in some instances further increase the thickness, by the addition of the regular rock, which must be cut through before the bed of coal is again discovered on the other side.

Thus, in fig. 6, *a a* is a dislocation, shifting the bed of coal *b b*; *c c* is the shattered strata on each side of the dislocation, which the miners generally consider part of the dyke. *d* is a mine cut through the regularly lying rocks, to connect the coal workings; and even this distance is considered by them as forming part of the dyke, improperly so called.

Fig. 6.



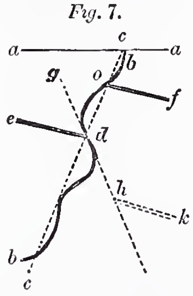
Dip or Inclination of Dislocations.—It may be stated generally, that dislocations assume a position varying but little from the vertical, an angle of 45° being an extreme case, nor do they ever occur in a nearly parallel position to the strata which they traverse.

When the stratification is highly inclined as in the edge coals, it might be expected that the dislocations were often nearly horizontal planes; but I have not been able to ascertain whether this has ever been noticed. On the contrary, observation and inquiry have led to the conclusion, that dislocations in strata of this description are generally found in a dip and rise direction.

The inclination of any dislocation is seldom uniform to any distance, but alters considerably at various depths, and at differpoints along its course.

Fig. 7 is a sectional view of a dislocation, where *a a* is the surface; *b b* the dislocation, presenting many angles of dip and rise at various depths; *c c* is the general line of dip and rise.

Fig. 7.



From this it appears that the sectional line of a dislocation, like the line exhibited by its horizontal course, assumes a general line of direction, subject to gradual undulations, but never presenting abrupt elbows.

The dislocations met with in a coal-field, are studied by the miner not only in reference to their declination from a vertical line, but also as related to the dip and rise of the coal which they traverse. For a dislocation may have an evident dip in a particular direction, when viewed in relation to a horizontal plane; and at the same time have a dip in a very different direction, when considered in reference to the inclination of the bed of coal.

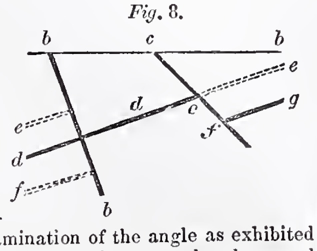
Thus in fig. 6, the dislocation *a a* dips towards the left in reference to the horizon, while in reference to the coal *b b*, it dips towards the right.

The importance of considering these circumstances will be at once admitted, when the following laws which govern the heave of the bed of coal are explained, as it will then be discovered that the angle formed by the plane of dip of a dislocation and the plane of the horizon do not in any way influence the result.

If a bed of coal lying in any position is intersected by a dislocation at an angle perpendicular to the bed, either no alteration in the position of the severed parts is produced by its interposition, or the coal is thrown up or down. At the place of separation, the coal may be loose and shaken, or even intermixed with clay and fragments of the adjoining strata; but in most instances, little if any observable displacement or alteration of level is effected.

In fig. 8, let *b b* be a dislocation, cutting perpendicularly across the bed of coal, *d d*. In this case, if any shifting of the coal takes place, it is doubtful whether it will be found at *e* or *f*.

Fig. 8.



If, on the other hand, the plane of fracture cuts the bed of coal at any other angle than a right angle, *a shift, heave, or slide of the bed of coal is the result.* And it is important to know that, from an examination of the angle as exhibited in the mines, the side on which the coal is elevated or depressed can at once be determined with accuracy.

Thus, in fig. 8, the bed of coal *d* forms an acute angle with the dislocation *c c*; and it will at once be known by the miner, in working from *d* towards *c*, that the bed of coal, instead of being found in its natural position *c e* on the other side of the dislocation, will be found lower down as at *f g*. This important law may be shortly expressed thus: If the dislocation forms an acute angle with the bed of coal between the roof and pavement on that side which is being worked, the seam will be lower on its other side; but if the angle be obtuse, the bed will be found at a higher level.

This general law admits of scarcely any real exception, although apparent deviations from it are not unfrequent.

In fig. 7, for example, the dislocation *b b* appears to cut the coal *e d* at an acute angle *e d g*, from which it might be hastily inferred that the coal on the other side would be found lower as at *h k*, while in reality it is higher, as at *o f*; and this error arises from ignorance of the true line of dip of the dislocation, which, instead of being on the line *g h*, is on the contrary represented by the line *c c*, which forms an obtuse angle with the bed of coal.

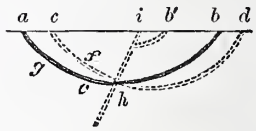
Great caution is therefore required in investigations of this nature, as much expense and disappointment may be occasioned by a partial view.

Another seeming anomaly is sometimes observed when the vertical heave is accompanied by a horizontal displacement which is very often the case.

For supposing a dislocation to traverse a basin-shaped coal-field in the direction *a b*, fig. 9, and to displace the coal so that

Fig. 9.

Fig. 10.



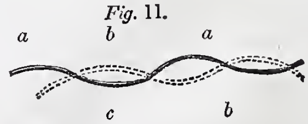
it will be lower towards *c*, and at the same time shift the whole stratification nearer to *b*, it will then be found that although every part of the bed of coal is now lower than it was originally, yet at the same time the coal will appear in some places higher, as at *e*, from the circumstance of a distant and originally much higher portion of the bed being now brought opposite and above that portion of the bed which remains unchanged. This arrangement will perhaps appear more clearly in the vertical section, fig. 10, where *a h b* represent the bed of coal in its natural position in the plane of the dislocation, and *c d* the position of a severed part, in consequence of a diagonal shift; here we find opposite *e* the coal apparently higher, as at *f*, contrary to the law just explained. This appearance is altogether fallacious, for the point *f* has been really brought down from *g*, and the part severed from *e* has been shifted to *h*.

In gradually exploring a coal-field like that represented by figs. 9 and 10, the true section of the dislocation will ultimately be discovered; but it may happen that the parts towards *a* in fig. 10, where the apparent deviation from the law was discovered, have been again cut off from the other parts of the basin, and shifted to a considerable distance, *i b'*, by a whin dyke, as *h i*, so that no clue will be left to free the inquirer from the difficulty.

If a dislocation traverses a bed of coal of an undulating character, and at the same time depresses the coal, and displaces it horizontally, it may appear at one place to elevate, and at another to depress the bed, although every particle of the seam is lower on one side of the plane of separation than the corresponding points from which they were severed on the other.

Fig. 11 is a section of an undulating bed of coal, *a a*; *b b* is its new position from the action of the dislocation; the point *b* has been shifted from *a*, and is now lowered, although at *c* it may appear to be raised up, which however is not the case. Appearances of this kind are not uncommon in a coal field traversed by dislocations of inconsiderable heave. There are real exceptions to

Fig. 11.



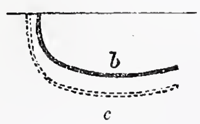
this rule; but the explanation of these is so involved with theory, that further notice of them must be omitted in this place.

Extent of Heave or Displacement produced by Dislocation.—This, of all the circumstances attending dislocations, is the one of greatest interest to the miner, and the one which occupies most of his thoughts; and although in many instances the magnitude of the heave may form a safeguard against inundations of water or inflammable air, it is yet too often the source of disappointment and great pecuniary loss. In an unexplored coal field great dislocations are met with most unexpectedly; and it is impossible to foretell the extent to which the workings may be deranged by the alterations they produce on the natural level of the bed of coal. They are found from the smallest step, which scarcely produces even the appearance of a ripple in the level, to a heave of many feet, and even hundreds of fathoms, which suddenly protrude from the district altogether the seams which were the object of the miner's laborious search.

The difference of level on account of heave produced by a dislocation in any seam of coal, seldom remains uniform throughout its course, but varies considerably in different parts of the field, either increasing gradually in a particular direction, varying irregularly at particular points, or beginning with a small shift; then gradually increasing in magnitude, and, ultimately lessening away towards its other extremity; and although, as we shall see afterwards, this difference may be occasioned by an actual change in the dip of the coal, consequent upon the action of the dislocation, yet in many cases the irregularity may be accounted for differently.

Thus, in fig. 12, *b* being the bed of coal, *c* is the new and lower position of the severed part. It is seen at a glance, that although every part of the bed is lowered to the same extent, yet the alteration may appear greatest at the centre and least at the sides, when the shift is estimated by a line perpendicular to the bed of coal, which is the common method amongst miners.

Fig. 12.



It is a singular circumstance, connected with the heave of a dislocation, that the alteration of level in the successive beds of coal, cut through in its upward run, is by no means uniform in all. The difference of heave in the various beds is often very great, but it has not yet been ascertained whether the heave is more considerable at the surface or in the deeper parts of the coal field.

It follows immediately from this, that the angle of intersection of a bed of coal and a dislocation, is no index to the amount of throw; although it is frequently found that the heave is greater in proportion to the obliquity of the angle.

It is not uncommon to find that a dislocation which shifts a bed of coal some feet, has no effect whatever upon other seams immediately above or below it.

Intersection of Dislocations.—It may be stated as a general rule, that dislocations never cross each other, it being almost invariably observed that at the point of intersection one of them entirely disappears. The more extensive dislocations generally continue their course, and the lesser ones run into these and disappear, and may thus be considered as mere branches or offshoots from the main fracture, or cross fractures between the larger ones. It has not therefore yet been proved that dislocations are of different ages, although this may be the case; and if so, important theoretical deductions would result.

Contents of Dislocations.—It has been already noticed, that the fractured parts of a coal field seldom adhere closely in their altered position, but are generally separated by some foreign substance. The intersecting mass is usually clay, when the cracks are of inconsiderable width; but when the fissures increase in magnitude, the clay either entirely disappears, or occurs intermingled with the debris of the associated rocks. Portions of the coal itself are not unfrequently found imbedded in the clay; and the colliers, by following these fragments to their source, even sometimes determine the position of the lost coal.

On approaching the outburst of a seam of coal, the fissures are often found to be filled up with sand, shingle, or mud, evidently infiltrated from above.

Changes produced by Dislocations on the surrounding Strata.—The changes produced by dislocations on the strata which they traverse are of various kinds, being either mere mechanical confusion in the texture of the various fractured rocks, chemical alterations in their composition, or more widely spread derangement in their thickness and inclination, or all these combined.

When a seam of coal is cut across by a dislocation, it is almost always much deteriorated in quality near the fissures. Its fracture becomes more irregular, and the joints are filled up with clay, iron pyrites, or calcareous spar, the coal loses its clear glossy lustre, and assumes a dull earthy appearance. The other rocks share in this alteration, being often much shattered and broken. These appearances extend frequently for many yards on both sides of the dislocation, and it sometimes happens that they are more extensive on one side than on the other. It would also appear that the distance to which the derangement extends from the dislocation, depends to some extent on the magnitude of the heave. When coal is in contact with a dislocation, it is not only rendered useless by its intermixture with earthy substances, but even the coal itself seems to lose many of its virtues; it no longer flames or smokes like ordinary coal, but burns with a dull red heat, like coke or cinder. This last appearance does not, however, invariably attend the action of a dislocation, although it is found to exist more or less near dislocations of great magnitude. The effect of trap-dykes in destroying the bituminous qualities of coal, have long been known; but the present remarks apply to mere dislocations of the strata.

Dislocations, particularly the larger ones, are found to alter the dip and rise of the coal considerably in their vicinity, either producing wave-like contortions in the bed and accompanying strata, or increasing the rate of dip uniformly to some distance. And it has often been observed, contrary to what we would expect to be the case, that, on approaching a dislocation which throws up the coal on the other side, the dip is downwards towards the dislocation.

All the appearances noticed above, are partial in their nature, and cease to surprise us when we become acquainted with the great changes produced by dislocations on the position of the strata, and when we reflect on the gigantic force which must have been exerted for this purpose. Another class of changes, however, present themselves in relation to this part of the subject, which cannot fail to excite the liveliest interest in the inquirer, and at once to engage his attention. I allude to the singular fact, that a great dislocation, in its passage across a coal-field, not only alters the original level of the various seams of coal, but also enlarges or diminishes the thickness of these coals considerably, and the separating strata, to the extent of many miles on one side of the dislocation. We may thus see a coal which has been worked extensively on one side of a dislocation suddenly thinned down to a half of its thickness on the other; or a coal which may have been worked as one seam, with a small parting of a few inches in its centre, unexpectedly appearing on the other side of the dislocation as two distinct seams with several feet between them. It is no doubt true, that a seam of coal is seldom uniform in thickness throughout a coal-field, neither is a parting, as it often alters from inches to feet; but yet it cannot be considered a satisfactory explanation to suppose, that distant and different parts of the stratification were brought opposite each other by means of a diagonal heave. This may account for the differences to some extent; but extensive and uniform alterations, like those just noticed, must owe their origin to a more general cause.

It has never been found that a bed of coal has been entirely lost on one side of a dislocation, or a new one introduced; but it is well known that a mere trace of coal of a few inches in thickness, is often found spreading over an extensive district; while on the other side of some great dislocation, it may increase to a good workable coal of several feet in height.

It is believed that the thinnings of the coal and accompanying strata take place on the down-throw side of a dislocation.

The general rate of dip of the whole stratification is often increased on one side of a dislocation.

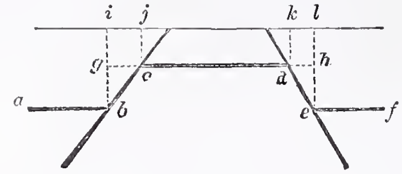
The Effect of Dislocations on a Coal Field.—In order to explain this part of our subject, reference for illustration must again be made to the simple basin-shaped coal field, lying under an even surface—although it is not intended to be implied that any such occurs in nature, either entire or cut up, and displaced by dislocations; but that, as being a form which presents fewer difficulties during analysis, its outlines are easily remembered, and easily contrasted with the new arrangements produced by

dislocations; and hence we are better able to estimate the change effected.

In a coal-field intersected by dislocations, every fracture produces a horizontal or forward shift of the strata.

Thus, in fig. 13, *a b c d e f* is the bed of coal altered by the dis-

Fig. 13.



locations *c b*, *d e*. It will be noticed here that the dislocations have pushed forward the bed of coal horizontally the distances *g c*, *d h* respectively.

It follows from this that in particular instances no coal exists at all at certain parts of the surface. Thus, in fig. 13, it is evident that at the surface, *i j k l*, no coal will be discovered.

A deduction must therefore be made in calculating the areas of a coal field, for vacancies produced by dislocations.

In a plan of a colliery, the vacant space between the workings of a shifted coal must not be confounded with the width of the dislocation, as it only represents the underlie consequent upon the amount of heave.

Where a coal basin is traversed by dislocations, it is found that the breadth of the field is apparently increased on the down-throw side of a dislocation, and diminished on the up-throw side.

Fig. 14 is a vertical section of a basin traversed by a dislo-

Fig. 14.

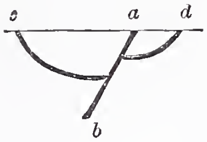
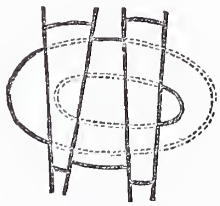


Fig. 15.

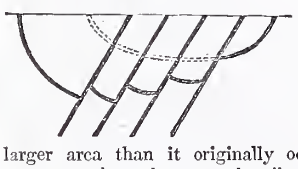


cation *a b*, throwing down the coal seam towards *c*, by which means the field is much increased towards that side, or diminished on the other. This is true, however numerous the dislocations may be, as shown by fig. 15.

The same law is observable when the dislocations run into each other, instead of being parallel.

It is often observed that a series of dislocations occur, running nearly parallel across a coal field, and throwing down the coal in one direction, like the steps of a stair, as in the vertical section, fig. 16.

Fig. 16.



It has frequently been stated, and is generally believed, that dislocations have the effect of spreading a coal field over a larger area than it originally occupied. This opinion, however, appears to have been too hastily admitted. If a series of parallel dislocations intersect a coal field, and throw the strata down in one direction, it is evident that the deposit will be spread over a wider extent of country; but if we consider these dislocations as having thrown the coals up toward a contrary direction, it must be admitted that the field is thereby diminished. Or, if again some of the dislocations throw the seam up, and some down, it is clear that their antagonist efforts will negative each other, and keep the basin nearly within its original limits. Nay, it is not improbable that the occurrence of dislocations in many instances may have had the effect of circumscribing the limits of the coal formation. Much has also been written regarding the advantages of dislocations in bringing up from the hidden depth of the earth the rich carboniferous deposits which we so fully enjoy in this country; but keeping out of view the question whether the subjacent parts were not rather lowered, a point on which we are entirely ignorant, it would be well to consider, before giving way to our admiration, whether more has not been lost by the upheaving and tilting of the coal strata than has ever been gained.

The remarks on the dislocations met with in the Scottish coal-fields, which have now been concluded, embrace the principal circumstances connected with their occurrence, although those involving theory have been omitted; but it is to be regretted that so little information on the subject has yet been collected. This will cease, however, to surprise us, when we reflect that the mines are seldom visited by scientific men—that those who understand the subject best have little leisure for imparting their knowledge to others—that the miners themselves are generally incapable of giving an accurate account of the appearances met with—and that those parts of the workings, where the most interesting phenomena would be disclosed, are generally abandoned or closed up, from the coal being no longer profitably workable.

GEOGRAPHY.

CHAPTER IV.

THE CHARACTERISTIC PHYSICAL FEATURES OF NORTH AMERICA, SOUTH AMERICA, AND OCEANIA.

IV.—Physical Aspect of North America.

The form of North America is that of a triangle, the base of which is the northern coast; the apex, the Isthmus of Darien; and the two sides, the eastern and western shores. Its physical features include a mixture of the most sublime, the most romantic, and the most picturesque scenery which can meet the eye of the traveller in any quarter of the globe. The alternations of lofty ranges of mountains, magnificent rivers, enormous lakes, boundless forests, gigantic trees, extensive prairies, and foaming cataracts, coupled with the singular appearance of the native tribes, cannot fail to fill the mind of the stranger with wonder, admiration, and awe!

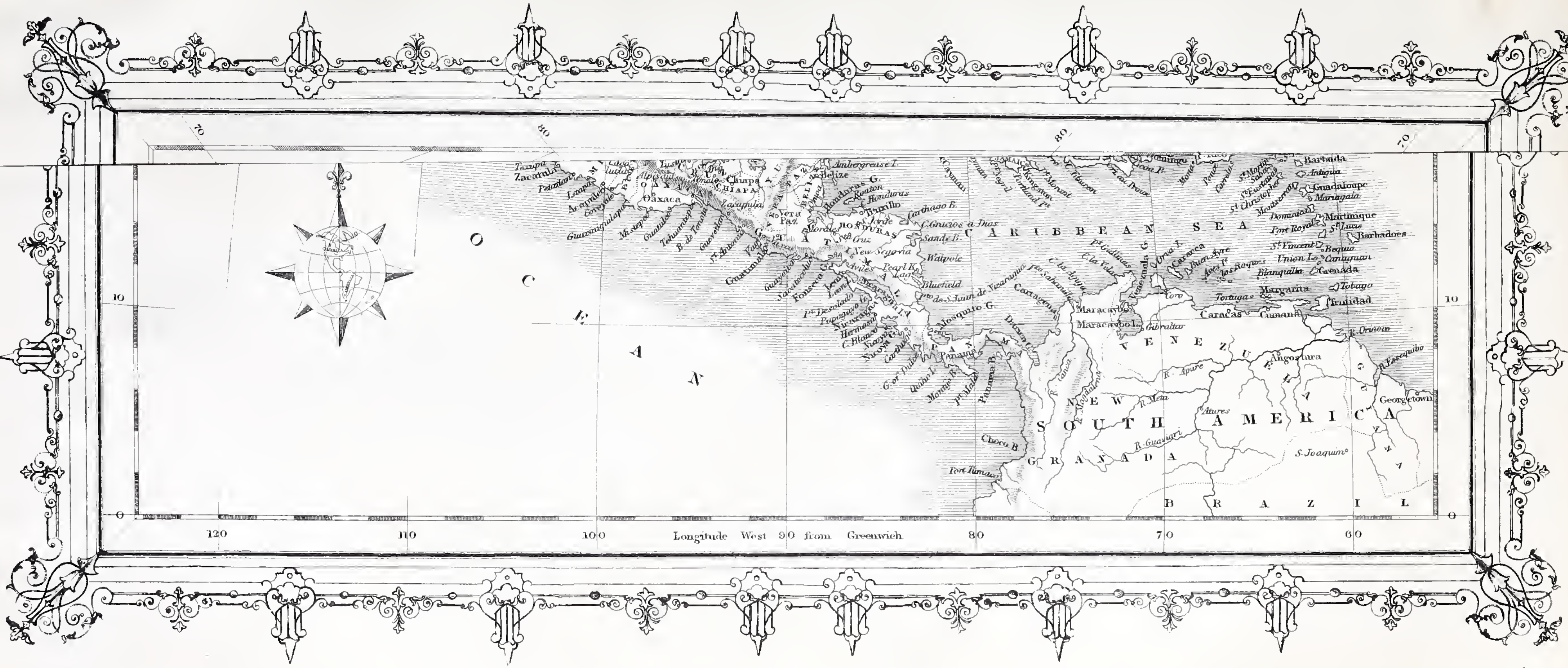
The characteristic feature of the northern portion of this continent, commonly called British America, is its vast chain of lakes—by far the largest bodies of fresh water on the globe—terminating in the great river St. Lawrence. These lakes are surrounded by extensive and dense forests of wood, consisting chiefly of different species of pines, covering, in many places, rich and luxuriant plains, which stretch far to the north. When the plains are cleared of this wood, they form soil of surpassing fertility and fruitfulness.

The country around *Lake Superior*, both on the American and British territory, is said to be cold and dreary, but is very imperfectly known; there is a great extent of hill and dale, some of the pine-clad mountains, near the lake, rising to the height of 14,000 to 15,000 feet above its surface. Mr. Schoolcraft describes the rugged and rocky scenery towards the south-east side of the lake as "surprising groups of overhanging precipices, towering walls, caverns, waterfalls, and prostrate ruins, which are mingled in the most wonderful disorder, and burst upon the view in ever-varying and pleasing succession."

Mr. Murray, in his geological survey, in the beginning of 1848, describes the north shore of Lake Huron as "poor, rocky, and, in some places, destitute of vegetation. In other parts it is thickly clad with trees of a stunted growth. But after passing these marginal forests of fir, spruce, pine, beech, and poplar, the interior in many places presents a very different character, especially on the banks of the different tributary streams, where there are frequently to be seen extensive valleys of rich and deep soil, producing maple, oak, elm, birch, and basswood; besides occasional groves of red and white pine, of large size. Various places of this description have been cleared and cultivated by the Indians."

From the east end of Lake Huron a range of mountains, called the La Cloche mountains, extends northward, which constitute the eastern boundary of a table-land, intersected by numerous small lakes and rivers, covered in several parts

NORTH AMERICA.



Scale of English Miles

200 0 200 400 600 800

by extensive forests and marshes, and occupied here and there by a few fur-hunting establishments.

Bounded by the river Ottowa on the east, and included in the irregular peninsula between Lakes Huron, Erie, and Ontario, is comprised a region which is nearly identical with UPPER or WESTERN CANADA. It consists of an extensive plain, adjoining the river and lakes, of two terraces, and a table-land.

The plain comprises about 20,000 square miles of fertile, alluvial, and well-wooded land. It has almost a uniformly level or slightly undulating surface; there is almost a total absence of stones; the forests are remarkable for trees of the richest foliage; in many places prairies, or natural meadows, extend for hundreds of miles, covered here and there with clumps of oak, white pine, and poplar, and presenting an appearance to which the park of an English nobleman cannot compare in beauty, and in magnitude it dwindles down into utter insignificance. With these advantages, and a delightful climate, it is not to be wondered at that colonization should have already made extensive progress in a region stretching between 42° and 44° of north lat.; and there is as little doubt that it will long continue to be the favourite spot where the hopes of the British emigrant will be centered.

Between this plain and the high table-land to the north-east, there are two terraces or slopes, extending from east to west, and separated by a range of hills. The first terrace is small, and extends quite down to Lake Ontario; it is very fertile, and tolerably well cultivated. The northern terrace is the larger of the two, and is about 50 miles wide; it contains numerous small lakes and a few rivers; its soil is fertile; but colonization has not yet proceeded to any great extent here.

The table-land comprehends the northern half of this region, and is, at an average, about 1,300 feet above the level of the sea. Near the centre of this elevated plateau, there are numerous lakes, most of which discharge their waters into the Ottowa, or Grand River. Lake Nipissing, near the north-west boundary, covers a surface of 155 square miles. This table-land is for the most part covered with wood, and is in the possession of the native tribes.

North-eastward of the junction of the river Ottowa with the St. Lawrence, is the region which is specially denominated the *Valley of the St. Lawrence*, and which comprises the whole of LOWER or EASTERN CANADA. Towards the mouth of the St. Lawrence, the ground on both sides is high and mountainous, and covered with forests to its very edge. On the northern side, the mountains run parallel with the river till we reach Quebec, when they take a westerly course. On the southern side, the mountains also run for a long way in the same direction as the river, but at a greater distance from its banks than on the northern side; and 60 miles below Quebec, they run off in a southerly direction into the United States. "From 100 miles below Quebec, to 100 miles above Montreal," says Dr. Thomas Rolfe, "on both sides of the St. Lawrence, there is a most beautiful country, not only cleared, cultivated, and thickly settled, but actually adorned with a continuous line of villages on either bank. There is not a point from which the spire of a spacious and elegant church does not greet the eye, and frequently there are many to be seen in the same view. The eastern portion of Canada, and probably the eastern townships, contain the greatest variety of beautiful scenery—mountain, rock, hill, dale, plain, forest, waterfall, lake, and river."

On the north side of the St. Lawrence, and towards the north and north-east, the country has been but little explored. From the Ottowa, to about 30 miles below Quebec, the north bank increases in height and boldness, and in the neighbourhood of that city the country is decidedly hilly. To the lowlands, which here and there occur on the banks of the St. Lawrence and its tributaries, succeed, as we go northwards, a series of terraces, then a range of gently sloping hills, and then a mountain chain, beyond which little is known.

On the south bank of the river, beginning with the western region, there is an extensive, and, for the most part, a level plain, with a very fertile soil and a dense population, occupying a considerable portion of Lower Canada, included in the above description of Dr. Rolfe. As we proceed down the river, the country becomes more hilly, presenting from sixteen to twenty miles of a gradual slope towards its banks; it then stretches out into a table-land, and afterwards descends towards the basin of the river St. John. Towards the peninsula of Gaspé, the country is hilly, and not so well adapted for colonization.

Proceeding southward to the commencement of the basin of St. John, the country becomes rugged and elevated, and towards the north and west is separated from the United States by many very high hills.

The greater part of the interior of the province of New Brunswick is still an uncultivated, though a beautiful wilderness. At a distance from the coast, it possesses an alpine character, with rich valleys, sheltered plains, and noble forests, in which many lakes occur, and streams wend in every direction, flowing either into the large river St. John, or falling into the Atlantic on the east.

To the south-east of New Brunswick is situated the peninsular province of Nova Scotia. It is pleasantly diversified with hill and dale—some of the hills attaining a height of from 800 to 1,000 feet. It is intersected and studded everywhere with rivers and lakes of every size and shape, which occupy such an extent of country as to cover nearly one-fifth part of the surface of the entire province.

Lying nearly due north from the Great Canadian Lakes, and occupying an extensive surface of the north-eastern portion of British America, the great Mediterranean Sea, called Hudson's Bay, penetrates the North American continent. It is connected with the Atlantic by Hudson's Strait, and with the Arctic Ocean by Fox's Channel; and is about 900 miles long and 600 miles broad. Around this large, but generally ice-bound inland sea, by far the greatest portion of the British possessions in North America, is generally known by the name of the *Hudson's Bay Territories;* they extend from the 49th to the 70th degree of north latitude, and from the Atlantic Ocean on the east to the Pacific Ocean on the west—a surface occupying upwards of 3,000,000 square miles.

It is difficult to convey a distinct idea of this vast territory; and, in our attempt to do so, we shall divide it into *five* regions:—

1st. The *Eastern* or *Sterile Region.*—The eastern division of this region lies between Hudson's Bay and the Labrador coast on the Atlantic, and it extends southward to a ridge of table-land, which runs nearly south-west to the source of the Ottowa river, and divides the waters which flow into that river and the St. Lawrence, from those which flow into Hudson's Bay. The western division of the sterile region extends from Hudson's Bay on the east, to the great lakes, Athabasca, Slave Lake, and the Great Bear Lake on the west, and to the Arctic Ocean on the north. The prevailing physical feature of this extensive tract of country is cold, rugged, and barren sterility; nothing to be seen but rocks, lakes, swamps, and barren mountains, buried under ice and snow for three-fourths of the year. The climate is rigorous in the extreme, even much more so than in Greenland in the same latitude; and almost the whole country is, on that account, left in the undisturbed possession of the Esquimaux, and a few forlorn families of Indians.

2d. The *Wooded Region.*—It lies along the southern and south-western shores of Hudson's Bay; it extends to the northern boundary of Upper Canada and the shores of Lake Superior. At some distance inland from Hudson's Bay, this region is tolerably well wooded, contains numerous lakes, produces fur-bearing animals, and affords employment to a number of "factories," or fur establishments, belonging to the Hudson's Bay Company.

3d. The *Savannah Region*—Lying westward of the former, and extending in this direction to the base of the Rocky Mountains, and northward to Lake Athabasca and the Peace River. The surface of this region is mostly a level plain, much intersected by rivers running in deeply cut channels;

its soil produces a thick grassy sward, which furnishes abundant food to numerous herds of buffaloes and several kinds of deer.

4th. The *Region of the Mackenzie River*—Lying north of Lake Athabasca, and included between the *sterile region* on the east, and the Rocky Mountains on the west. The valley of the Mackenzie River only extends two or three miles from its banks, till about ninety miles from its mouth, where it spreads out into a delta of from 15 to 40 miles in width, and is intersected by various branches of the river. The banks of the river are composed of alluvial soil, which is pretty well wooded.

Viewing, then, the whole of the extensive territory between the Rocky Mountains and Hudson's Bay, north of the 49th degree of latitude, as one region, it may be considered as a series of lakes, rivers, plains, swamps, treeless hills, and hollows, "tossed together in a wave-like form, as if the ocean had been suddenly petrified while heaving its huge billows in a tumultuous swell."—*Simpson's Life and Travels.*

The whole country dips eastward towards Hudson's Bay. Extensive portions of this region, particularly towards the north, are sterile and desolate in the extreme; vegetation ceases at 60° north latitude; no land is seen capable of cultivation; the whole surface is rugged, and devoid of all vegetable productions.

5th. The *Rocky Mountains, and the Columbia Region*—Lying between these mountains and the ocean—a distance of from 400 to 700 miles. The granitic mountain chain, called the Rocky Mountains, runs parallel to the Pacific Ocean, and bounds the region of Columbia on the east and north-east; their average height is 8,500 feet, some peaks rising to the height of 15,000 to 16,000 feet; their width is from 50 to 100 miles. The country which commences at the western base of these mountains may be considered as an uneven plain, with an average width of 100 miles; a great portion of this plain is covered with lakes and swamps, but the vegetation in summer is very luxuriant. Along the Pacific coast the country is very mountainous, the isolated peaks of the chain being covered with snow for a great part of the year. The natives of these dreary regions are in a wretched condition.

The region to the west and north-west of Columbia, is called *Russian America;* it is a large peninsula, stretching between the Pacific and the Polar Sea, terminating at Behring's Straits on the west, and is the least known portion of the north-western coast of America. It is dreary and unproductive, and inhabited by ferocious tribes of Indians; and its only use to Russia, to which it belongs, arises from its producing fur-bearing animals.

The vast portion of North America, called the UNITED STATES, stretches across the whole continent, from the shores of the Atlantic Ocean on the east, to the Pacific Ocean on the west; and from the great Canadian Lakes and upper portion of the river St. Lawrence; and, farther westward, from the 49th degree of north latitude on the north, to the Gulf of Mexico on the south.

This immense territory is traversed by two ranges of mountains, which divide it into three regions:—1st, The Appalachian chain, including the Alleghany Mountains, runs in several ridges nearly parallel to the Atlantic coast, in north-easterly and south-westerly directions, to a distance of 1,200 miles; and, 2d, The chain of the Rocky Mountains (whose northern termination we have already described), is a continuation of the high lands of Central America and Mexico; they stretch northward, parallel to the Pacific coast, and present a chain of elevation upon a much grander scale than the Appalachian system.

The Appalachian Mountains form what is called the great water-shed, or dividing line, between the waters which flow eastward into the Atlantic Ocean, and those which flow westward into the Mississippi. They cover an area of about 100 miles in breadth, only one-third of which is occupied by the mountain chains, the rest consisting of intermediate valleys, in which the numerous rivers flow. This series of mountains runs at very unequal distances from the coast; in some parts, towards the north, the Atlantic almost washes their base; while towards the south, in the Carolinas and Georgia, it is distant about 200 miles.

The region between these mountains and the Atlantic coast includes what are called the older States of the Union, where, consequently, civilization has made most progress, and where agriculture has made the greatest encroaches upon the once densely-wooded forest. It is intersected by numerous rivers, none of which, however, from their short courses, are of any great magnitude. The land on the sea-coast is level, and much indented by numerous bays and gulfs; the soil here is generally sandy, and in many parts barren, except on the banks of the rivers, where it often possesses an extraordinary degree of fertility; as we recede from the coast, the country becomes greatly, and generally agreeably, diversified with hills and valleys. These valleys possess a rich and fertile soil. Towards the south, the level and extended plain adjoining the coast, presents a boundless monotony of forests, swamps, marshes, and level fields, which, for the most part, are extremely barren.

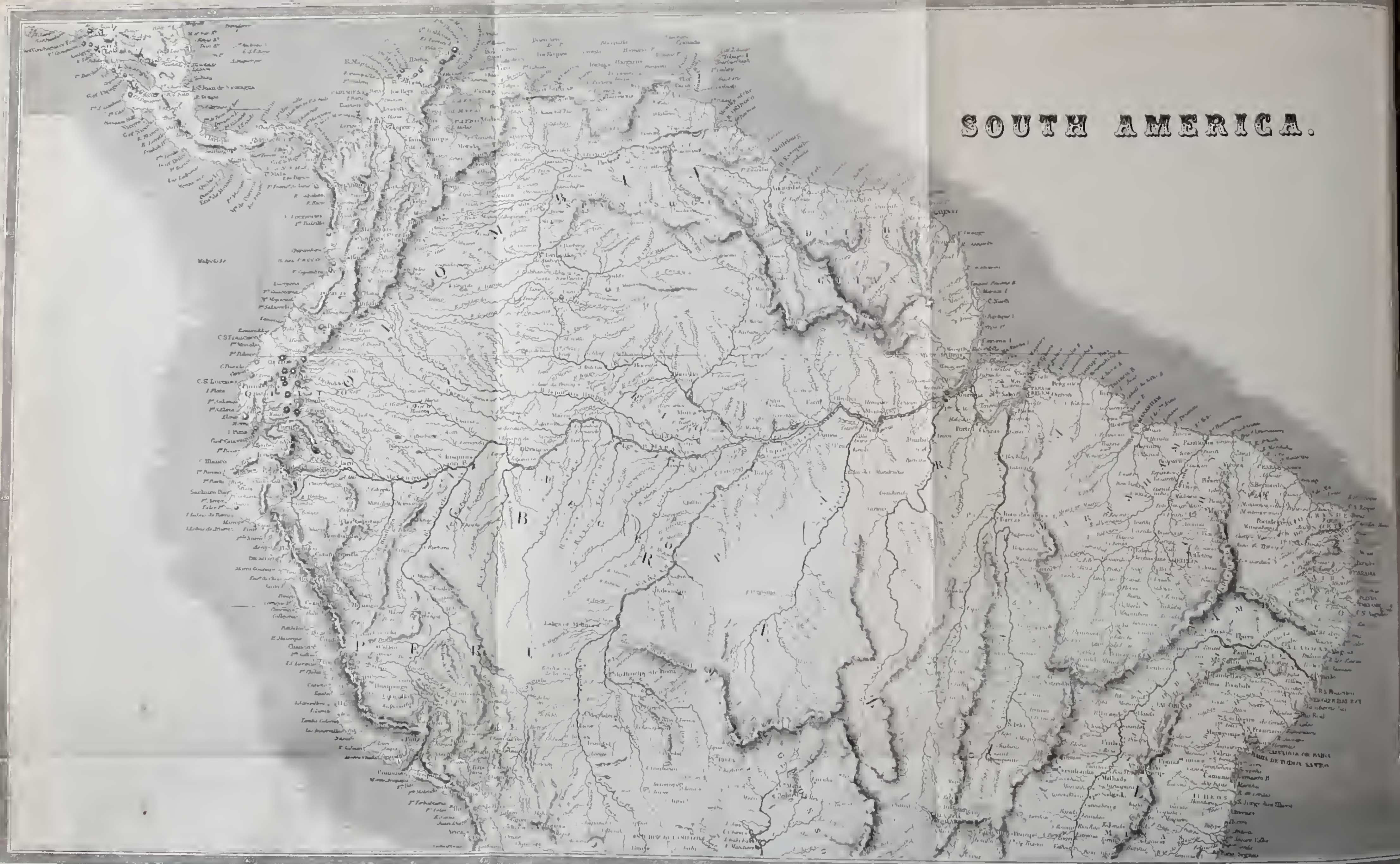
The region between the two mountain systems above described, is denominated the *Valley of the Mississippi*—a river, the second in extent in the world, and draining a surface of upwards of a *million* square miles of country.

The western slope of the Appalachian chain of mountains falls by a gentle but broken descent to the Mississippi—a region upwards of 1,000 miles in length, and about 300 miles in width, with no elevation but gently rising hills, and deeply furrowed by numerous rivers over its whole surface. Adjoining the mountains, the country possesses a wild and broken character, in some parts fertile, but generally barren. When America was first discovered by Europeans, the whole surface of the vast territory between the Atlantic and the Mississippi presented an immense natural and unbroken forest, interspersed here and there, on the western side of the Alleghanies, with open and naked plains, called *prairies*, clothed with grass, herbage, and flowers, and presenting, in the month of May, the most enchanting scenery. The clearings which have been effected, since its first discovery, in this vast ocean of trees, by the indefatigable industry of the Saxon and Celt, are even yet insignificant compared to the great extent of surface, and appear but specks, barely discernible in a general view.

As we approach the Mississippi on the eastern side, we have mostly a champaign country, with occasional hills of moderate elevation, covered with pine forests, and interspersed with swamps, open prairies, and inundated marshes; a considerable portion susceptible of cultivation, and many parts possessing a rich and fertile soil.

The region west of the Mississippi, and for a considerable distance from its banks, partakes of the character of the eastern side, consisting of an immense plain, divided into pine woods, prairies, lakes, swamps, and hickory and oak lands. As we proceed westward, we reach wide-spreading steppes, clear of wood, scorched in summer with intense heat, and in winter subject to a most intense degree of cold, produced by the winds from the Rocky Mountains. Northern Texas and the upper regions of the Arcansas are analogous in their physical aspect to the high plateaus of the Asiatic continent; while we find a country stretched along the base of the Rocky Mountains, of an average width of five or six hundred miles, which is emphatically called the *desert.* "The name of *savannahs*," says Malte Brun, "is given to those vast prairies of the western region, which display a boundless ocean of verdure, and deceive the sight by seeming to rise towards the sky, and of which the only inhabitants are immense herds of bisons or buffaloes." "In the country west of the Mississippi," says he, "wood is comparatively scarce; and in the arid and desert plains, occupying a breadth of from three to four hundred miles to the east of the Rocky Mountains, only a few trees are to be seen on the banks of the rivers."

Although a great portion of this region is barren towards the Mississippi, many parts of the states of Arcansas, Missouri, and Iowa, are very fertile, and susceptible of culti-


SOUTH AMERICA.

vation; the state of Iowa, in particular, is said to contain a large portion of land of very superior quality.

The innumerable streams which run eastward to feed the great Mississippi and Missouri rivers, take their rise in the Rocky Mountains, to which we have already alluded. This gigantic range of mountains, many of whose tops rise to an elevation of from 11,000 to 15,000 feet above the sea, and are covered with perpetual snow, divides the western territories of the United States, from California and Oregon—territories which lie between this mountain range and the Pacific coast, and which have only been a few years annexed to the Union. This mountain chain has a breadth of from 50 to 100 miles; it rises abruptly from the Plains of Texas, some of the peaks being visible at the distance of 100 miles. The western, or Pacific declivity, is not so abrupt as the eastern; and towards the north, where they constitute the eastern boundary of the Oregon territory, both sides, instead of passing into plains, terminate in hilly regions of considerable extent. Among the ridges and peaks into which these mountains are divided, there occur, towards the south, many wide and fertile valleys; but towards the north, they are cut up, in some parts, by deep and precipitous ravines, and covered with dense and gloomy forests; and, in other parts, particularly towards the western side, there occur wide depressions in the hilly regions, which are well-watered prairie lands.

The *Oregon Territory* is divided into three regions, by two ranges of mountains, which run nearly parallel to the coast—the Blue Mountains and the Cascade Mountains. The region between the Blue and Rocky Mountains is arid and barren, and uninhabitable by those who depend on the soil for subsistence. The general appearance of the country for some distance from the coast is flat, but it gradually rises from hills of moderate elevation, to rocky and snow-clad peaks of a great height. The whole of Oregon is drained by the river Columbia and its tributaries, on the banks of which the only fertile land is found. The valley of this river comprises all the open space between the Rocky Mountains and the Pacific; here, as well as in many other places along the coast, wood is abundant, some of the trees reaching an enormous size. Pine trees are said to be found, having attained the height of 300 feet, with a circumference of from thirty-six to forty-five feet, presenting a solid trunk for upwards of 170 feet, without a single protruding branch. In the interior there are extensive plains, or prairies, without wood; they are covered with grass, and spangled in spring with a profusion of beautiful flowers. The climate, among the mountains in the interior, is severe in winter, with a great deficiency of rain and moisture in summer; but towards the coast, it is said to be much milder than on the Atlantic coast in the same latitude.

Our description of the physical features of Oregon will nearly apply to the neighbouring territory of *California*—a country which has become so much celebrated within the last few years by the discovery of its extensive gold fields. California is situated between Oregon and Mexico, and is divided into *Upper* and *Lower* California. Upper California lies adjacent to Oregon, and consisits of a strip of flat country, of sandy and barren soil, extending all along the Pacific coast, and inland to the distance of 100 to 200 miles. Then we have a mountain range, and after that, as we proceed eastward, we reach the valley of the river Colorado. In the north-eastern extremity of the territory, we have the valley of the Tule Lakes, which, in the rainy season, occupy a surface of 100 miles in length. The surface of Upper California is covered to a great extent with rocky mountains, and consequently possesses but a small portion of fertile soil; but in some places, where it is arable, it is said to possess an unusual degree of richness.

Lower California is almost wholly composed of high, bare, rocky, and barren ground, with many ravines, and very few flat plains, or spots capable of cultivation. The aspect of the country is wild and sterile, and greatly resembles Upper California.

The most remarkable feature in the physical aspect of the southern portion of North America, constituting the apex of the triangle to which we compared that continent, is the extensive plateau or table-land which occupies the greater portion of Mexico and Central America. "On the eastern and western coasts are low countries, from which, on journeying into the interior, you immediately begin to ascend, climbing, to all appearance, a succession of lofty mountains. But the whole interior is, in fact, thus raised into the air from 4,000 to 8,000 feet." It is the most elevated plateau in the world, the capital town, Mexico, being situated 7,000 feet above the ocean. The eastern declivity of the southern portion of the plateau, next the Mexican Gulf, is a continual and rapid descent; but the western slope, towards the Pacific Ocean, alternately ascends and descends through several remarkable longitudinal valleys. The table-land of Mexico Proper, on the other hand, descends very rapidly towards the Pacific, but more gradually towards the Mexican Gulf.

The shores of Yucatan are a sandy and flat plain, which extend a considerable distance inland; farther north, on the western coast of the Gulf of Mexico, the level plain is covered with a thick and luxuriant forest, composed of alluvial soil, extending inland to a distance of from 50 to 120 miles, and often liable to be inundated; further north still, the eastern coast is low and sandy. Behind this low and level coast, and at the distance of 60 to 180 miles from the sea, the country gradually rises to the bottom of an extremely steep ascent, which leads to the high table-land to the west; this ascent rises in some places in terraces, in others it often rises from 5,000 to 6,000 feet in a distance of less than ten miles in width. The outer edge of the elevated plateau, towards the east, is lined by a continuous series of hills, two of which rise to upwards of 13,000 and 17,000 feet in height. The elevated plains are divided by two ranges of mountains, which traverse them in an eastern and western direction, and they occupy by far the greatest part of the surface of Mexico.

The general aspect of the *West Indian Islands* is mountainous, many of the mountains affording striking proofs of their volcanic origin. They are all possessed of a soil of extraordinary fertility, and abound with almost every kind of tropical production.

V.—Physical Aspect of South America.

"We now enter," says Malte Brun, "upon the richest and most fertile—the healthiest—the most picturesque—and, excepting Africa, the most extensive peninsula of the world."

"In the physical arrangement of the parts of South and North America, there is a remarkable resemblance. Both are very broad in the north, and generally contract as they proceed southward, till they end, the one in a narrow isthmus, and the other in a narrow promontory. Each has a lofty chain of mountains near its western coast, abounding in volcanoes, with a lower ridge on the opposite side, destitute of any trace of internal fire; and each has one great central plain, declining to the south and the north, and watered by two gigantic streams—the Mississippi, corresponding to the Plata, and the St. Lawrence to the Amazon."*

The form of South America, like that of North America, may also be compared to that of a triangle; of which the north-west point is the isthmus of Panama; the north-east, Cape St. Roque; and the south, Cape Horn.

The physical geography of South America is simple and uniform. It may be divided into three regions—a western plateau, with a general elevation of 10,000 feet, crowned by chains and peaks of isolated mountains of an immense height; a middle region, consisting of a vast expanse of country, composed of marshy or sandy plains, and intersected by three enormous rivers, with their tributaries; and an eastern region, consisting of another plateau, but much less elevated, and of a less extent than the western.

The great mountain system of South America is the Andes, or *Cordilleras*, a range of mountains running along the western side of this continent, parallel to the Pacific, and extending from the Isthmus of Panama to Cape Horn. They consist of a series of mountain chains, more or less parallel to one

* Encyclopædia Britannica, seventh edition—article, *America*.

another, enclosing vast elevated plains or table-lands, and of several distinct groups at distant intervals. These table-lands are perfectly level, and placed at immense heights above the ocean; but in extent they are not to be compared to those of Mexico. The inhabitants of these elevated plains have no conception of their height above the sea, (some of them being upwards of 13,000 feet above its level,) the Andes appearing to them at a distance as merely isolated peaks of moderate height. The valleys of this great mountain system are described by Humboldt as being truly sublime;—deeper and narrower than those of the Alps and Pyrenees, the valleys of the Cordilleras present situations so wild as to fill the mind with fear and admiration. They are formed by vast rents—frequently 2,000 feet deep—with a stream generally running through their middle, the whole abyss being clothed with a vigorous vegetation; many of them are of such a depth, that the mountain of Vesuvius might be placed in them without overtopping the nearest heights.

The whole of the interior of South America consists of level plains, denominated in one part *Llanos;* in another, *Pampas;* and in a third, *Silvas.* This central region is occupied by the basins of three large rivers—one of them the largest in the world—the Orinoco, the Amazon or Maranon, and the La Plata. The basins of these rivers are separated by water-sheds of slight elevation; in no region in the world, indeed, do we find three such enormous river basins separated by elevations so trifling.

The basin of the Orinoco on the north comprises the *Llanos*, or vast plains, which occupy a surface of 260,000 square miles, and the chief characteristic of which, according to Humboldt, is the absolute want of hills and inequalities, every part of the soil being so perfectly level, that spaces of 270 square miles can be found on which there is not an eminence of a foot high. In some places, however, there are horizontal banks of sandstone or limestone, many leagues in length, which stand four or five feet higher than the rest of the plain; in others, there are eminences rising to the height of a few fathoms. The aspect of the Llanos is very different in different seasons of the year; in the rainy season they display a beautiful verdure, but in the dry season they assume the aspect of a desert. The great wealth of the Llanos arises from the countless herds of wild cattle which they feed, and which were first introduced and let loose in the country by the Spaniards in 1548.

Pampas, occupying the basin of the La Plata, is the name given to those extensive level plains by which the southern and central parts of South America are occupied. They extend from the Andes to the Atlantic at Buenos Ayres, and cover a surface of about 315,000 square miles, which slopes very gently towards the east. The southern part of this immense plain is sandy, and covered with patches of saline plants and stunted trees; the northern parts are covered with wood, and afford pasture to immense herds of cattle and wild horses.

Silvas is the name given to the wooded part of the great plain of Maranon, or Amazon, which is one of the most extensive continuous plains in the world, occupying a surface of nearly 2½ millions of square miles. Of this surface, 719,000 square miles are covered with primeval forests, the rest being occupied by waters, and by open patches, similar in character to the llanos and savannahs, but it is in a great measure unexplored.*

The eastern region of South America comprises a considerable portion of Brazil, and is occupied partly by plains, and partly by a series of mountain ranges, some of which rise in many places to a height of upwards of 7,000 feet. Some of the minor ranges of mountains enclose elevated plateaux, much lower certainly than those already described, but higher than any in Europe.

A great portion of the upland, or mountainous region of Brazil, both on the mountains and in the valleys, consists of a poor soil, often sandy; in summer it is burnt up, and the country has a dismal aspect, but in the rainy season it is generally clothed with a coarse grass, bushes, and single-standing trees. Many parts of the Atlantic coast have a climate like that of Italy, are watered by numberless streams from the mountains of the interior, and, consequently, contain a more fertile soil.

Brazil, like the greater part of the South American continent, is little cultivated, and the chief source of wealth arises from the domestic animals which are reared, and find abundant pasture in the immense plains with which the country abounds.

VI.—Physical Character of Oceania.

The physical aspect of this portion of the globe is so little known, that a very short description must suffice, and if we can succeed in imparting a general idea of the appearance of the numerous islands of which it consists, we must rest satisfied.

Malaysia, or the East India Islands, are throughout of a very mountainous nature—Mount Ophir, in Sumatra, rising to the height of 13,050 feet. These islands are all of volcanic origin, and where they do not rise into mountains, they are covered with impenetrable jungle and unhealthy swamps. Where soil capable of cultivation exists, it is of the most fertile description, capable of producing every tropical production in luxuriance; before it is subjected to cultivation, it is covered in general with forests of stupendous trees.

Australasia comprehends Australia, Van Diemen's Land, New Zealand, New Guinea, and several other islands and island groups to the eastward. The physical aspect of Australia, so far as known, is generally flat, but slightly undulating, containing, except near the coast, but few mountain ranges, and, what is very peculiar, inclined in many places *inwards* towards the interior, instead of *outwards* to the sea.

With few exceptions, the whole of Australia is surrounded by a belt of mountains from 2,000 to 6,000 feet high, branching into collateral divisions, and at a distance from the coast of 50 to 100 miles. The inner slope is least precipitous, declining, in several parts, in successive terraces, through which some rivers flow, either to be absorbed in the burning sands, or to go to the formation of immense marshes in the interior.

The plains or grassy flats are of vast extent, and, being almost clear of wood, afford the finest sheep pasture in the world, when not burned up by the destructive droughts which occasionally occur.

Almost the only known portion of this vast island is towards the southern, south-eastern, and south-western coasts, severally denominated—South Australia, Victoria, the Sydney district, or New South Wales, and Western Australia. Victoria and the Sydney district have lately acquired a world-wide celebrity, from the extensive gold fields which have been discovered over a great extent of their surface, and for which so many thousands of our countrymen are weekly leaving their native land.

Van Diemen's Land has a picturesque and beautiful appearance, presenting an endless succession of lofty mountains wholly covered with wood, and interspersed with high rocks and precipices, glens and hills, with occasional flats or plains.

A lofty chain of mountains intersects the islands of New Zealand, which throws out spurs or buttresses on each side, separated by deep ravines, and precipitous intervening valleys. The soil is very fertile, and the climate delightful.

The other islands in this section are generally mountainous, and covered with lofty forests.

Polynesia is the name given to the numerous clusters of islands scattered over the central parts of the Pacific Ocean. They are either of the volcanic or coral formation: the former being steep, rugged, and lofty; the latter, elevated but a few feet above the sea, and appearing as long, narrow, or circular reefs. Where these islands are mountainous, they are covered with wood of luxuriant growth; and where they are cultivated, they possess a soil, for richness and fertility, unparalleled in the world: the climate is delightful, and the scenery enchanting, and—

"All but the *spirit of man* is divine."

* The shores or banks of the river Amazon, and many of its tributaries, are very low, and apt to be overflowed in the rainy season. The rivers, lakes, and intersecting water-courses are so numerous, that this plain presents an enormous amount of water surface. These waters, and the interminable forests, are the most striking features of the plain of the Amazon.

THE ELECTROTYPE.

CHAPTER VII.

EXPENSE OF DEPOSITING COPPER—COATING IRON WITH COPPER—BRONZING—COATING OF IRON WITH ZINC AND OTHER METALS.

HAVING in our previous articles on the subject, shortly described the principles and operations of electrotyping in copper, we shall go on to the consideration of the methods of operating with other metals, and to the application of electrotype processes to some of the arts and manufactures of this country. We have, in our illustrations of the subject, selected for examples the formation of copper medals and busts. Electro-metallurgy is, however, applicable to the production of articles of every variety of form; and, before proceeding to the methods of electrotyping with other metals, and especially with gold and silver, we must refer briefly to other applications of the process of coating with copper, and the limit which is set to these applications by the important consideration of cost. The subject of *bronzing* also demands our attention in connection with the use of copper as the deposited metal, and then we shall proceed to detail the most approved methods of depositing other metals, and especially of electroplating and gilding.

The expense incurred in the production of articles in electrodeposited copper, by the most economical and practical method, averages two shillings per pound. Mr. Smee, in his "Advice" to capitalists who propose entering upon the business of electro-metallurgy, gives a table of expenses incurred by the use of different batteries. We refer to this, as we are aware that several individuals have been led astray by it. It is to be borne in mind, that Mr. Smee recommends for use what he calls "an odds-and-ends battery," being composed of odd scraps of zinc put into acid, having in the same vessel a piece of copper or platinized silver; a wire is placed in contact with them, which forms the electrode. This battery is very convenient for the amateur electrotypist, as it enables him to use up all his otherwise waste zinc. Raw zinc, or spelter, Mr. Smee says, may also be used in this way, and constitutes the cheapest of all batteries for manufacturing purposes. The results of his calculations are as follow:—The copper sheet forming the positive electrode is quoted at 1s. per pound; wrought zinc, 7d. per lb.; raw zinc, at little more than half of wrought zinc, which we will say 4d. per lb., although he rates it at 5d. Then he gives the equivalent weights of copper, zinc, and iron, which are respectively, 32, 32, 28; that is, 32 grains of copper being deposited, there will be destroyed in the battery, 32 grains of zinc, or 28 of iron. The equivalent, or 32 grains, of zinc, is quoted at a cost of $\frac{1}{40}$th of a penny; and the equivalent of iron at $\frac{1}{75}$th of a penny. Following the same proportions. we have the following items of expenditure when raw zinc is used:—

	s.	d.
16 oz. of copper, . .	1s.	0d.
16 oz. of raw zinc, . .	0	5
	1	5
When iron is used—		
16 oz. of copper, . .	1	0
14 oz. of iron, . . .	0	3
	1	3

But although the above are the rates which he gives, yet by a long algebraic equation, he finds that

Copper deposited by iron single cell, per lb. costs 1s. 6d.

Copper deposited by odds-and-ends battery, per lb. 1s.

Now, it is not easy to see that, while a pound of copper originally costs 1s., it could be deposited by the destruction of 1 lb. of zinc, not including acid, &c., at the expense of only 1s. It ought always to be remembered, that for manufacturing purposes, the surface upon which the metal is to be deposited, in general amounts to several square feet. The article may be, for example, a large ornamental vase, having four square feet of surface. An odds-and-ends battery, or an iron single pair battery, would be too weak. If, after waiting three times the usual time for the deposition of 32 oz. of copper, the operator were to take out his zinc, he would be very fortunate if he escaped with the loss of only 50 or 60 oz. of it. To deposit upon a surface such as that of the vase already mentioned, with a separate battery, requires two or three pairs of plates to give what we call economical power. Now each pair must be multiplied by the equivalent of metal used: thus if it be zinc, 32 oz. of copper will, by calculation, require $32 \times 3 = 96$ oz. of zinc with a three pair battery. The actual loss is more than that now found, on account of impurities and other causes. Besides, when the surface deposited upon is four square feet, the surface of zinc in the battery, only reckoning one of the zincs, may not exceed two square feet. This creates a loss of nearly half the time, that is, it requires double the time for deposition: hence, when the article allows of it, we prefer the porous system for the sake of economy, as by this means we obtain a surface of zinc equal to the surface of the article; and if the process be properly arranged, the power will be sufficient. We find that, on this system, under the most favourable circumstances, for four square feet of surface having an equal surface of zinc, 32 oz. of copper are deposited in 30 hours with an expenditure of

	s.	d.
36 ounces of zinc, which costs . .	0s.	10d.
and 126 ounces of sulphate of copper, which costs	2	8
	3	6
This divided by 2, gives the price per lb. .	1	9

leaving only 3d. per lb. for acid, cells, and other sources of expense, to make up our statement, already given, of 2s. per lb. All these calculations, we may mention, bear reference exclusively to copper from the sulphate of copper; and they appear to preclude the possibility, in a commercial point of view, of manufacturing by the electrotype process such large plain articles as saucepans and the like. But for producing articles of intricate workmanship, in respect of either casting, engraving, or chasing, the process is invaluable.

The electro-process is applicable also to the covering of wood-work, terra cotta, cornices, &c. This may be done at a comparatively small cost, as a mere film of copper deposited upon the surfaces of these articles will be sufficient: 32 oz. of copper will yield a fair coating for 40 square feet of surface. Iron-work may likewise be made to assume the appearance of solid copper at very little expense. However, the covering of that metal with copper requires careful manipulation. It is a familiar fact, that if a piece of iron, as the blade of a knife, be dipped in sulphate of copper, it receives a coat of copper; but this is easily rubbed off; and if the iron were allowed to remain in the solution, it would very soon be destroyed. The electrotypist, however, may not use any salt of copper which has this effect upon iron. Several salts of copper are found wanting this property, but they are not all equally useful for the purpose. The salt which we prefer, is cyanide of potassium and copper. Cyanide of potassium is prepared by intimately mixing 8 parts of well-dried yellow prussiate of potash, pounded into powder, and 3 parts of dry carbonate of potash. Portions of this mixture are from time to time thrown into a crucible (an iron one is to be preferred) which is deposited in a furnace, and heated to redness. This process is continued till the crucible is nearly filled, being also kept as closely covered as possible. The whole becomes in a short time one beautiful liquid mass, which is occasionally stirred, until that which adheres to the rod assumes a white colour when cool. The crucible is now removed from the fire, and allowed to stand till the solid particles sink to the bottom. The clear fluid is then poured off into a clean iron vessel, and allowed to cool. It constitutes cyanide of potassium, containing about 25 or 30 per cent. of impurities. This substance may be made at 3s. per lb., and is as good as what is sold by apothecaries and chemists at from 2s. to 3s. per ounce. The cyanide of potassium and copper may be prepared by various processes; but that which is most generally adopted, is to add cyanide of potassium to carbonate of ferrocyanide of copper till they are

dissolved. We prefer the latter mode, as the ferrocyanide of potassium which is used may be recovered. It is thus prepared: To a solution of sulphate of copper is added, by degrees, a solution of yellow prussiate of potash, so long as a precipitate is formed. A large vessel should be used for this purpose, as the precipitate is very bulky. When it has subsided, the clear fluid is poured off, and the vessel is again filled up with clean water, which is in like manner allowed to settle, and the clear again poured off. This operation is repeated four or five times, until the precipitate is well washed. The chemical action which takes place during precipitation, may be represented thus:—

Yellow prussiate of potash.	Cyanide of iron,	1	1. Prussiate of copper.
	Cyanogen, . .	2	
	Potassium, . .	2	
Sulphate of copper.	Copper, . .	2	2. Sulphate of potash.
	Sulphuric acid,	2	

To the brown precipitate of prussiate of copper, a solution of cyanide of potassium is added till the whole is dissolved; there results from this the cyanide of potassium and copper with ferrocyanide of potassium. Thus—

Ferrocyanide of copper.	Cyanide of iron,	1	5. Prussiate of potash.
	Cyanogen, .	2	
	Copper, . . .	2	
Cyanide of potassium.	Potassium, .	2	
	Cyanogen, .	2	
	Cyanide of potassium, .	2	6. Cyanide of potassium and copper.

The solution thus obtained is ready for operation. It should be wrought at a temperature of 150° Fahrenheit, and requires four or five pairs of battery power. It yields a beautifully coloured deposit. By a little evaporation and crystallization, the yellow prussiate will crystallize first, and may thus be separated and kept for use again in a similar operation.

When it is required to cover an iron article with copper, it is first steeped in hot caustic potash or soda, to remove any grease or oil; being washed from that, it is placed for a short time in dilute sulphuric acid, consisting of about one of acid to sixteen of water, which removes any oxide that may exist. It is then washed in water, and scoured with sand till the surface is perfectly clean, and finally attached to the battery, and immersed in the cyanide solution. All this must be done with despatch, so as to prevent the iron from combining with oxygen. An immersion of five minutes' duration in the cyanide solution, is sufficient to deposit upon the iron a film of copper. But it is necessary to the protection of the iron, that it should have a considerably thick coating; and, as the cyanide process is expensive, it is preferable, when the iron has received a film of copper by the cyanide, to take it out, wash it in water, and attach it to a single cell or weak battery charged with sulphate of copper. If there is any part not sufficiently covered with copper by the cyanide solution, the sulphate will make these parts of a dark colour, which a touch of the finger will remove. When such is the case, the article must be taken out, scoured, and put again into the cyanide solution till perfectly covered. A little practice will render this very easy. The sulphate solution for covering iron should be prepared by adding to it, by degrees, a little caustic potash, so long as the precipitate formed is redissolved. This destroys a great portion of the sulphuric acid, and thus the iron is not so readily acted upon.

By the above process, any iron-work may be so perfectly coated with copper, that it can with difficulty be distinguished from solid copper. Figures, medals, &c., which have been covered and exposed to the weather for some years, have indicated no symptoms of rust, but have taken on a beautiful bronze appearance, as if the figures were cast in that metal. Such figures may afterwards be plated or gilt, by a process which will be afterwards described.

BRONZING.

In concluding our remarks on the depositing of copper—a metal so extensively used for medals, and other electrotyping operations—it would be improper to omit the process of *bronzing*, which is useful for preserving medals and other objects from tarnishing, for bringing out the workmanship with better effect, and for imparting an agreeable variety to the cabinet of the amateur. "If proper precautions are taken," says Mr. Walker, "the medals from the fusible moulds will *generally* present a bright *copper* surface; occasionally, however, they will present a very *brilliant* surface, greatly resembling *silver*. When this is the case, they may be placed, without further trouble, for the cabinet. The silvery tint is only obtained on *first* specimens; it would seem that the surface of the *new-made* mould is covered with a metallic film, which attaches itself *firmly* to the surface of the deposited copper. It is so firmly attached, that it may be polished with a leather or plate brush, without sensibly affecting it. If specimens of this description are exposed to the air, they will occasionally require the application of the plate brush to restore their primitive brilliancy."

It is usual, however, to give medals and ornamental objects a coating of bronze, that they may acquire a permanently agreeable appearance. This is effected in various ways: the bronzing may be brown, black, or green; and the selection of the method adopted is entirely a matter of taste. To avoid sameness of appearance in a cabinet, the amateur is recommended not to confine himself to one method; and therefore we shall here give brief directions for imparting a permanent tint of each of the three colours mentioned.

A very good *brown* bronze is obtained by adding to a wine-glass of water, four or five drops of nitric acid. The medal is first to be carefully cleaned from oil or grease; and is then to be wetted with this solution, and allowed to dry. When dry, it is exposed to a gradual and equable heat, and the bronzing, or darkening of the surface, will proceed in proportion to the heat applied.

Another very beautiful brown bronze is obtained by the simple application of plumbago, or black-lead. The medal, being previously cleaned from wax or grease by washing it in a little caustic alkali, is brushed over with black-lead, and is then placed in an oven, or laid on an iron plate over a clear fire, until it is too hot to be touched. In this state, a few strokes of a plate brush will produce a dark-brown polish, approaching black, but entirely distinct from the appearance of black-lead. If the medal has been kept for some days, or carefully polished, the same operation will impart to it a rich, brilliant, and agreeable colour, between red and brown.

A dark-coloured bronze is obtained by dipping the medals into weak acid solutions of platinum, gold, antimony, &c., and then washing and brushing them. If a darker colour, approaching black, is required, the medal is washed with dilute sulphuret of ammonia, and dried at a gentle heat. It is then polished (but care must be taken not to scratch) with a hard hair-brush. Any sulphuretted alkali may be used, although the ammonia is preferred.

To communicate a green bronze is an equally simple operation, but requires a little longer time. For this purpose, the medal has only to be steeped for some days in a strong solution of common salt, or of sal ammoniac; it is then washed in water, and allowed to dry slowly. Immersion in a strong solution of sugar, or exposure to the fumes of dilute acetic, or to weak fumes of hydrochloric acid, and to several other vapours, will answer the same purpose. The solution of sugar is improved in effect by the addition of a little acetic or oxalic acid. A fine *antique* green bronzing is obtained by suspending the medal in a dry covered vessel, in the bottom of which has been placed a little bleaching powder. A few grains of the powder are sufficient, and the depth of the coating may be regulated by the time of exposure. The tints also may be varied, according as the medal is clean or tarnished, dry or wet, when suspended.

In concluding this part of our subject, Mr. Walker's hints with reference to mounting the medals may here be appropriately introduced. "I have adopted," says that gentleman, "a method of mounting the medals obtained from the *fusible* moulds, which gives a finish to their appearance. I obtain pale green cards, the size of visiting cards, and cut some of these into single squares; *the width* of the card being the side of the square: others into smaller squares, *half the length* of the card forming the side of the square. A pencil circle is

drawn the size of the medal; and two *ink* circles in order to 'throw' the medal 'forward.' The part within the pencil circle is cut out, and waste cards are cut to fit the extra edge of the medal. The two cards being fixed together with very strong gum-water, the medal is placed in, and secured by another card gummed on at the back. The obverse and reverse are then gummed back to back, and thus the appearance of a perfect and solid medal is produced, equal, in point of workmanship and beauty to the original. To hold the cards together until the gum dries, I use cleft-sticks. The medals obtained from wax-moulds, having no addition to the edges, are not well fitted to be mounted thus: they may simply have any roughness removed from their edges with a sharp file, and be placed in the cabinet without being fitted with cards."

COATING OF IRON WITH ZINC.

Having now concluded our remarks on the methods of electrotyping with copper, we proceed to describe the processes of operating with other metals, all of which may be deposited by means of the galvanic current, with various degrees of facility and economy.

Lead is a metal sometimes used for covering iron by the electro process; but there is little to recommend it for this purpose, being so soft, that a little friction takes it off, and its electric tendency hastens the destruction of the iron. The solution of lead commonly used for the purpose is the oxide or cyanide dissolved in caustic potash. Tin is very easily deposited, but its application by deposition is not economical, as the salts of tin that are the most easily deposited from, are the least permanent. Tin is applied to the surface of other articles, by the common process of melting it and washing them over with it. Nickel is very easily deposited, and would form a most excellent covering for other metals; but the great difficulty exists in getting a positive electrode, from the unmanageable nature of that metal; and to work without an electrode renders it necessary to be constantly adding oxide to the solution of the crystallized salt, which would render the process so expensive that it would be better to deposit a covering of silver at once.

Zinc is a metal much used for the covering of iron by the electro process for the purpose of protecting it against rust. We have stated above, that the coating of iron with copper requires a peculiar and careful manipulation—a circumstance arising from the fact that iron is positive to copper, and therefore the acids have a stronger attraction for it than for the latter metal. On this account, we have seen that instead of the sulphate of copper, the cyanide of potassium and copper must be used to procure the deposit on iron. In covering iron with zinc, however, the same precautions are not required, zinc being the positive metal; and, accordingly, the process is simply performed by depositing the zinc from its sulphate. This process has been patented by the Messrs. Elkington. From one to two pounds of the crystallised salt are dissolved in one gallon of water; the iron is cleaned, as already described for receiving the coating of copper, and attached to the negative terminal of the battery, and immersed into this solution. A separate battery must be used for this process, and a battery of one pair is sufficient. As the solution is easily decomposed, vast quantities of iron work are covered in this way, and the coating affords an excellent protection to it under all ordinary circumstances. For screws and bolts that are driven into wood, it is invaluable.

"The voltaic influence of zinc for protecting iron," says Mr. Napier, "is a subject which has occupied the attention of practical men for a long time: it is one of high importance; nevertheless, there seems yet a great deficiency in our knowledge of the extent of this influence, and how and when it is effective." We conceive, therefore, that it will not be out of place to devote the remainder of the present chapter to some remarks, with a view to the elucidation of this important subject, which formed the substance of a paper read by Mr. F. Pellat at the Institution of Civil Engineers, so long ago as in May, 1844.

The cause of iron becoming corroded is its superior affinity for oxygen: this causes it to decompose water, and combine with its oxygen. If the iron and water are both pure, this is not, indeed, found to be the case; but, under ordinary circumstances, *neither* of these exist in a state of purity: the iron, therefore, owing to its own impurity and that of the water, is subject to a powerful destructive influence, which is best known to those most experienced in its use; and there is no circumstance in which we can place iron to be free from the action of water, it being present in the air and earth. So powerfully is this metal affected in the earth, or in contact with some salts, that it loses all its essential properties, and is converted into a substance so soft that it may be scratched by a finger nail. These facts render it of the utmost importance that some means be obtained for its protection, which, at the same time, will not interfere with the natural properties of the iron. The substances hitherto used for protecting iron are tin and paint. These, as lasting coatings, are not effective. The tin being electrically negative to the iron, renders it a means of destruction, instead of protection, when any part of the iron is exposed. By the laws of electricity, when metals are in contact, the negative metal is protected at the expense of the positive; circumstances, such as different chemical menstrua, may alter the relative electrical states of metals; but, under all ordinary circumstances, this rule holds good; and zinc being the positive metal, it becomes in consequence a protector to the negative metal iron. This electrical property of zinc, in connexion with iron and other metals, has induced those, to whom it was known, to recommend it as a coating. The difficulty hitherto has been the obtaining of zinc pure, and the application of it without injuring the texture of the iron. From the known qualities of zinc, it has been lately much employed for various purposes, but has entirely disappointed the expectations formed from its properties. The reason of this is, that no zinc of commerce is pure, and that the impurities existing are destructive to it from the electrical law we have alluded to. The impurities existing, more or less, in all zinc, are lead, iron, arsenic, and one or two other metals, all of which are electrically negative to zinc—the consequence being that every atom of impurity, in connexion with the zinc, forms a galvanic battery: thus a battery of many thousands, or rather millions, of pairs of plates, is formed, the impurities being protected, and the zinc destroyed. It has no doubt surprised many who have made use of zinc to find it in a few weeks or months, according to circumstances, perforated with small holes, and completely destroyed. We say according to circumstances; because the *ordinary time* zinc lasts depends not only on the amount of impurities contained in it, but also on the exciting fluid to which it is subjected. Exposed to the action of water from the atmosphere, the destructive influence operates comparatively slowly, but with more exciting fluids very rapidly. Thus, a roof erected in the neighbourhood of a vinegar distillery was completely destroyed in six weeks, and vessels used for dairy purposes have lasted but a very short time, owing to the presence of acids—these causing a rapid galvanic action between the zinc and its impurities. It is then quite evident, that impure zinc, being itself valueless, cannot afford protection to any other metal. Now, the only process formerly in use for the coating of iron with zinc, was that of immersing the iron in melted zinc, and this we conceive open to many objections. The iron, by this process, being raised to a temperature of at least 800°, causes it to combine with the zinc, forming an alloy on the surface, which changes its state, and becomes brittle. But, upon this subject, we shall refer to the report made by M. Dumas to the French Academy. He says, "the zinking of iron, made by steeping iron in a bath of melted zinc, has many inconveniences; besides, the iron combining with the zinc constitutes a very brittle superficial alloy; the iron loses its tenacity—a circumstance which is not perceived, however, except in trying to zinc fine iron wire, or very thin plate;—besides, the surface being covered with a layer of not very fusible metal, is always ill-formed. Thus, fine iron wire cannot be zinked by this process, as it becomes fragile and deformed; bullets cannot be zinked, as they become misshapen, and no longer of the same calibre." We have reason to believe, that very nice manipulations, and annealing the iron after zinking, may remove some of M. Dumas' objec-

tions to this process; still, two fatal objections, in our opinion, would exist to its use; first, the impossibility of obtaining *pure* zinc, except at an enormous expense, the only process being sublimation or distillation; and, secondly, the impossibility of retaining its purity during the process of applying it to iron. Setting aside the fact of an alloy of iron and zinc being produced by the action of heated iron immersed in melted zinc, the presence of foreign matter necessary to retain the zinc in fusion, renders it impure; these matters forming less fusible compounds, and zinc being very volatile, a great amount of waste is created.

But it is well known to all those who are acquainted with the deposition of metals from soluble salts by the electro process, that pure metal only is deposited, so that this process is not open to the objection upon this head which may be made to every other, more especially in treating a metal of so intractable a character as zinc. It is also applicable to all sizes and shapes of work; requires no expensive erections; and, what is important in large operations, may be performed anywhere, and by any person. Although the protective influence of zinc (we of course speak of pure zinc) upon other metals is practically unknown, it has been well known to men of science, and we shall take the liberty of quoting the opinions of some of the best chemists upon the subject, bearing in mind that zinc is electrically positive to other metals, and as such protects them from oxidation at a very trifling loss to itself—and that by a well-known law of electrical science, one body being electrically excited, that body induces its opposite state in other bodies with which it is in contact. Keeping these three points in view, we would call attention to the following opinions:—Sir John Kane says, "Zinc preserves the other metals, even if it be iron, from oxidation;" and again, "zinc, when exposed to the air, even in presence of water, becomes covered with a varnish of a gray substance, probably a definite suboxide, which is not further altered by exposure." Professor Graham, alluding to iron in water, says, "articles of iron may be completely defended from the injury occasioned in this way by the more positive metal zinc, while the protecting metal itself wastes away slowly;" and further, when speaking of zinc, "When exposed to air, or placed in water, its surface becomes covered with a gray film of suboxide, which does not increase; and this film is better calculated to resist both the mechanical and chemical effects of other bodies than the metal itself, and preserves it." And the late Professor Daniel remarks, "that a plate of pure zinc, when immersed in water, speedily becomes dulled by the formation of a thin coat of oxide, but the oxidation proceeds no further, because the adhesion of the metal prevents a renewed contact of the metal and the water." From these authorities we notice that pure zinc has a double protecting influence, the iron being protected by the zinc, and the zinc by its own oxide, besides that peculiar galvanic influence induced by the positive state of the zinc with respect to the iron. With regard to the peculiar adaptation of the electro processes to the zinking of iron, we shall again quote from M. Dumas' Report:—He says, "manufacturers, and those concerned in military affairs and the fine arts, will learn with interest, that these processes enable us to zinc in an economical manner, iron, steel, and cast iron, by means of the pile or battery with the solution of zinc, by operating without heat, and consequently not interfering with the tenacity of the metal, by applying it in thin layers, and by thus preserving the general forms of the pieces, and even the appearance of their minutest details. The thinnest plate may receive this preparation without becoming brittle, and may be turned to account in roofing buildings."

We hope these authorities fully support what we have asserted, that pure zinc affords a perfect protection to iron, is not itself susceptible of rapid decay, and is easily applicable to the electro process. We are aware that other opinions upon this subject have been given; some have almost denied its galvanic influence, and have reduced it to what they term a *mere "tendency,"* whilst others have much overstated it. Effects which may be witnessed every day, prove that there is a secret galvanic agency at work when metals are in contact. Take for instance the decay of iron when in contact with lead. Every one has observed that iron railings let into stone work with lead are much decayed within a short space of the contact of these two metals, whilst the remaining portion is comparatively sound. This effect is from the iron being positive to the lead, which is therefore protected at the expense of the iron. On the other hand it has been urged that the galvanic influence of zinc upon iron is so powerful that even if some portion of the iron be exposed, it will not oxidize by the protection afforded by the galvanic influence of other portions in contact, to those at a distance. In ordinary circumstances this is not correct; the atmosphere does not contain sufficient moisture to afford a conducting medium for the electricity generated; and wherever the zinc is removed, oxidation will take place; but this will not extend to those parts where the metals are in contact. But where a conducting medium such as water does exist, the zinc affords protection to the iron, even to those parts at a considerable distance from the contact of the metals. Thus we have known a large water-wheel in action for fifteen years, and in an excellent state of preservation, having been protected by small portions of zinc connected in various parts of the iron work. These parts in contact generated sufficient electricity to protect the whole wheel, the water affording the conducting medium required. The zinc of course wastes away, but is renewed as required. It is matter of regret that zinc cannot be used with the same protecting property to articles in use at sea. This arises from its strong affinity for muriatic acid, thereby forming muriate of zinc, which being readily soluble, is taken off by the water, leaving a new surface of zinc to be acted on, thus rapidly destroying the zinc. This we state theoretically, and not from practical experience. Some articles have been zinked and sent to sea with the view of ascertaining how far this opinion is borne out by practice. In situations where the articles are not exposed to the run of salt water, we are inclined to believe that the zinc will be found a protection, more especially in ship's bolts which are in a situation to be protected from the action of sea water, the moisture of the wood supplying a conducting medium for the electricity to such parts of the iron work from which the zinc may be removed. We shall proceed, in next chapter, to describe the methods of coating with the finer metals, and especially those of electro-plating and gilding.

FLAX,

AND THE PROCESSES OF ITS MANUFACTURE.

CHAPTER IV.

HISTORY AND STATISTICS OF THE MANUFACTURE.

The history of the flax manufacture relates chiefly to Ireland. That part of the United Kingdom is perhaps more peculiarly identified with it than with any other department of natural production or of manufacturing enterprise. The existence of the flax industry has been so cherished, and its progress so anxiously watched and recorded, that its history, which we may date back from the commencement of the past century, is readily traced, and can be told in a few lines. In 1699 we find that an act was passed for the regulation of the linen manufacture, which provided for the appointment of a board in Ireland, to be entitled, "Trustees for Linen and Hempen Manufactures," whose duties were to encourage in every way the proper culture of the flax plant, and to regulate and improve its manufacture into linens, the entire control and direction of the culture and manufacture of flax being vested in them. This board, however, did not assemble for business until October, 1711, when it met under the auspices of the Duke of Ormonde, the Lord-Lieutenant. For the first twenty-five years the funds at its disposal averaged about £6,000 a year; subsequently they were increased to £20,000, a sum which was fixed upon by Parliament as the annual grant during the greater part of its existence, which terminated in 1828. Notwithstanding the numerous abuses which the *bounty system* naturally produced, the Linen Board, through the stimulus

which it gave to the manufacture generally, especially by the great increase in the production of the raw material, was productive of much benefit to the nation. At this period (1828) we find the area under cultivation to amount to about 80,000 acres, and little or no further progress was made until 1841, when, the necessity for some organized influential body having been acknowledged, a new society was formed at Belfast, under the title of the "Society for the Promotion and Improvement of the Growth of Flax in Ireland," under whose judicious and invigorating auspices flax industry now enjoys a higher state of prosperity and a more healthy development than it has ever hitherto possessed. In 1841 the quantity of land under flax cultivation was 83,745 acres, of which 81,131 acres were in Ulster, and 2,314 acres in the other provinces. In 1851 this had increased to 138,619 acres, of which 123,728 were in Ulster, and 14,891 in other districts. Ulster appears always to have produced the great mass of the raw material, the relative increase in the production of the other provinces being due entirely to the exertions of the society. The principal obstacles to its culture in those districts have been—firstly, the want of scutching-mills for preparing the fibre; and, secondly, the want of local markets for the sale of it. These are being met, to a considerable extent, by the establishment of retteries and scutch-mills by the landed proprietors, assisted by Lord Naas's recent bill, which enables them to borrow the requisite capital from the Government on the same terms as drainage loans; and also by the establishment of flax-markets in the larger towns, at which Belfast agents regularly attend. If these advantages are properly met by the growers, the increase in production will, no doubt, be continued, as both the climate and the soil are well adapted for the plant. Notwithstanding the excellent directions circulated by the society, the tillage operations often appear to be very carelessly performed, and a practice, still persisted in throughout the country, where the grower steeps his own produce, tends much to obstruct improvement, and also to reduce the amount of the market returns. It is calculated that the produce of at least 100,000 acres of flax was steeped last year without the seed having been taken off, and that the latter, at mere crushing prices, was worth at least £300,000. This practice is the result of ignorance on the part of the farmer, and of a defective industrial system, which will be speedily changed by the establishment of retteries and scutch-mills, where the farmer will meet with a ready market for his produce, without having to attempt any portion of a manufacture, for which neither his conveniences nor his capacity are generally adapted. He will then be left to his legitimate occupation, that of producing the raw material, for which he will obtain an immediate return, instead of the risk and uncertainty of his present process. This would, to a great extent, resemble the "factorage" system, which works so well in Belgium, and which the society endeavoured a few years since to introduce into Ireland, but which partially failed, owing to the great difficulty of inducing the farmers to dispose of their flax in a raw state. Because they paid out no money for labour in steeping, they considered the value of their flax straw as equal to what they would have obtained for it in the state of dressed fibre, which left no margin for the factorage and subsequent operations.

The consumption of flax in Ireland has been doubled within the last ten years. In 1841, the spinning trade numbered 250,000 spindles; in 1851 it was close upon half a million. In the place of 16,000 tons, the amount of consumption in 1841, 32,000 tons are now required by the trade.

The principal markets for flax, to supply the spinning trade of the three kingdoms, are, respectively, Leeds, Belfast, and Dundee, in each of which there are commission-merchants, to whom flax may be sent for sale. The principal flax-mills in England are in the West Riding of Yorkshire, and in Lancashire, Dorset, Durham, and Salop.

Up to a late period in the past century, all the yarns were produced by hand-spinning, which was carried on in farm-houses and cottages throughout the country. These yarns were brought into the nearest town on market-days, when they were purchased either by the weavers, or by agents, who supplied them to other persons; or, in many cases, the female members of a family spun the yarn, which was woven by the men. In 1795, the first machinery for spinning flax was erected at Darlington, in England; and, as it was speedily proved that yarns could be thus produced both better and cheaper than by hand, it was soon extended. At this time the flax was spun dry, and only coarse yarns produced. In Ireland we find that the first spinning factory was established at Cork, in 1805, and consisted of only 212 spindles, adapted for canvass yarns. The Linen Board, by a bounty of 30s. per spindle, succeeded in causing the establishment of several others, which in 1809, in the aggregate, contained 6,369 spindles. In 1815, there were in Ulster five mills, the largest having 1,204, and the smallest 300 spindles; in Leinster two mills, and in Munster seven—only one of which was in full operation, owing to the depression of trade at that period.

The necessity, however, of increasing these spinning-machines was shown in 1825, when English and Scotch machine-spun yarns began to be imported into Ireland, and completely undersold the handspun product. These yarns were produced by an improved system, termed "wet spinning," the fibre, during the process of twisting, being, as already stated, passed through hot water. By this mode, invented by Kaye, of Manchester, it could be spun much finer; and by degrees, aided by continuing improvements, the quality and fineness of the yarn were so much changed, and the economy of labour so much attended to, that the handspun yarns were completely superseded, except for fine cambrics. The first factory of any magnitude on this improved system was established in Ireland in 1828. Others soon adopted it, and new ones sprang up. In 1841, we find there were 41 mills, containing 260,000 spindles; in 1850, the number had increased to 73 mills, with 339,000 spindles; and in 1852, there were no less than 81 mills, having about 500,000 spindles in operation, representing an amount of capital invested in buildings, machinery, and in the necessary commercial operations, of between three and four millions sterling. About two-thirds of the mills are situate at Belfast and its vicinity, which, being the centre of the linen trade, and possessing great advantages in respect to the supply of skilled labour and cheapness of fuel, is considered preferable as a locality to the more rural districts. As the employment of machinery for spinning increased, the linen manufacture appeared gradually to withdraw from the south and west, and to concentrate itself in the north, where the spinning factories were principally situate. With the exception of Drogheda, and, to a small extent, Cork and Mayo, scarcely any linens are now made beyond the boundaries of Ulster. To form a correct estimate of the development of the industry in Ireland, we have only to compare it with its condition in England and other countries. In England, the last report gives the number of spindles at 265,568, and in Scotland at 303,125, giving, with Ireland, a total for the United Kingdom of 1,068,693. In France we find the number of spindles to be about 350,000, the factories being situate chiefly in the departments Du Nord, Calvados, Finisterre, and Pas de Calais. In Belgium there are about 100,000 spindles in operation, the factories being at Ghent, Malines, Brussels, Liege, and Tournai.

Holland possesses only one factory, of about 6,000 spindles, in Friesland. In Switzerland there are three or four small establishments, working from 8,000 to 10,000 spindles in all. Russia has two large factories, one at Alexandrofsky, and the other at Moscow, together numbering about 50,000 spindles. Spain has two or three, containing, say, 6,000 spindles. Austria possesses eight factories, with about 30,000 spindles in operation. In the States of the Zollverein, about 80,000 are estimated to be in use; and in the United States we find 12 small factories, situate in the states of New York, Pennsylvania, Massachusetts, and New Jersey, and numbering between them 14,550 spindles. Now, reckoning the average cost of buildings, machinery, and motive power, at £4. 10s. per spindle throughout, it would appear that there is altogether a *fixed capital* of £8,000,000 invested in this trade, of which sum nearly £5,000,000 belongs to the United Kingdom. Notwithstanding these large returns of machinery for spinning in operation both at home and abroad, we find that the handspun yarn very far exceeds it in quantity, since, throughout the

continent, hand-spinning is still carried on to an enormous extent.

The yarns spun in Irish mills are in general medium numbers, suitable for both coarse and fine linens; the numbers suitable for cambrics, lawns, &c., are chiefly the production of the English mills, and the very coarse yarns for canvas, bagging, and other rough goods, are those generally spun in Scotland. Besides yarn-spinning, a large and increasing trade is done in twisting sewing threads, which either as brown, bleached, or dyed, command an extensive sale in Great Britain and on the continent. One kind of bleached thread, made by a peculiar process to resemble silk, has lately been sold largely to the Nottingham lace-makers.

The substitution of machinery for hand labour in weaving is a natural consequence of its successful application in the spinning process. In England and Scotland the manufacturers have eagerly availed themselves of its manifest advantages. In Ireland a power-loom is, as yet, rarely to be seen, so difficult is it, under ordinary circumstances, to introduce a change in the established practices of a craft. If we turn to the Factory Inspectors' Report for 1850, we see, to our astonishment, that in England there were 1,131 power-looms at work, and that in Scotland there were 2,529, while in Ireland the entire number amounted only to 58. But the linen districts in Ireland are now affected by *more than ordinary* circumstances, and it is no longer possible to disguise the fact that they cannot meet the present requirements of the market either in quantity or in price. The two most important causes affecting them are "emigration" and "cheap food." The Ulster weavers have chiefly been small farmers, cottiers, or labourers. At seed-time and at harvest they were in the fields; during the other part of the year they were at their looms. The farmers were enabled to obtain their subsistence from their potato crop, a portion of which they ate, while the remainder fed their pigs, or was sold in exchange for other necessaries. Their rents were not paid by their produce—that all went to their subsistence—but by the money earned at their looms, which also met their wants for clothing, tea, and other cheap luxuries. The potato blight annihilated the small farms, and their occupiers shoaled off to the western world. The cottiers and labourers are left still; but, between the wages they earn from farm-labour and from their looms, they can now, by working only four or five days in the week, live as well as they used to do in the old days of "Protection," when they were forced to work hard the whole week. From these two causes, it results, firstly, there are fewer weavers now than there were in 1846; and, secondly, those that remain turn out fewer webs.

Since 1846, however, the demand for Irish linens has progressively increased both in the home and foreign markets; consequently, the demand increases in a progressive ratio over the power of supply; while, at the same time, the competition for hands has increased the cost of labour, which, in respect to cheapness of production, places Ireland at a great disadvantage when she has to meet the Belgian and the German in those foreign markets where she has gradually supplanted them. In fact, it appears that, within these few last months, Belgian goods are competing successfully with Irish in some of the South American markets. This condition of the Irish linen trade demands the immediate and serious consideration of every one connected with it. Every day is of importance, as a retrograde movement has commenced, and must be arrested at once. Two points must be gained—an increase in the quantity, and a decrease in the cost of production. The first might, to a certain extent, be obtained by the employment of additional hand-looms in other districts; but the south and the west are not equal to the wants of the north. Both might be obtained by the use of *power-looms*. England and Scotland have already shown how advantageously they can be used for coarse goods. Surely Ireland, with such a future threatening her staple manufacture, will produce men with both the energy to attempt, and the skill to overcome, any little mechanical difficulties that may occur in adapting them for finer goods. In Glasgow, indeed, this has recently been accomplished; thus, while the practicability of the process for Ireland is proved, another and a vigorous rival will take possession of the field.

Some of the bleachworks in Antrim are on an extensive scale, and are conducted with great skill, giving employment to a large number of hands. Near Lisburn, the two firms, Messrs. Richardson, employ about 300 hands each, and in the course of the year bleach goods, having a market value in the aggregate of about £1,200,000 sterling. The improvements in the spinning and in the bleaching processes have been followed by a great reduction in the price of the manufactured goods, the sale of which has enormously increased. The relative prices of yard-wide linen in 1805 and in 1850 were as follows:—

	14°°	18°°	20°°	22°°	24°°
1805	2s. 0d.	3s. 4d.	4s. 4d.	5s. 11d.	10s. 6d.
1850	1s. 2d.	1s. 8d.	2s. 1d.	2s. 6d.	3s. 6d.

The quantities produced were more than doubled, being about 45,000,000 yards in 1805, and 110,000,000 in 1850. This increase is due chiefly to the export trade; the home consumption, not being so much affected by reduction in price, has not increased in the same proportion. One cause, probably, for this is the immense progress of the cotton manufactures after the employment of machinery in spinning cotton wool, which caused a corresponding increase in the home consumption of its fabrics many years before the linen manufacture, in its turn, participated in the same facilities of production; hence cotton rapidly increased in consumption among the lower classes of the United Kingdom, while linens continued to be worn only by the better classes. The export trade has steadily increased for a series of years. Under the Linen Board, bounties were paid on the export of several kinds of fabrics, the last having ceased only in 1830. Although these bounties, in the earlier period of the manufacture, tended to encourage an export trade, the true source of its late increase has been in the improvement in the spinning and general manufacture, which permitted a gradual reduction in price, and thus supplanted the Belgian, German, and French manufacturers in neutral markets. At one period the supply of South America and the West Indies was chiefly in the hands of the Germans; but the Irish trade advanced so much more rapidly, owing to various improvements, that German linens almost entirely disappeared, and the Irish, until quite recently, commanded the market. One kind of Irish linen largely sold in South America is termed "Selisias," and is made up in imitation of the goods formerly supplied by that province in Germany. The New World takes the great mass of linen exported, those sent to the eastern hemisphere being of very trifling amount in comparison.

From returns recently published we find that 39,000,000 of persons in America consume annually more than two yards of our linen per head, while 228,000,000 in Europe take but one thirty-eighth part of a yard per head. This difference does not arise so much from the consumption being proportionably less in the countries of the Old World as from the high duties which most of the European States maintain on the import of these fabrics, and from the small disposition to use them in Asia and Africa, where cotton fabrics are almost exclusively used. It is more than probable that a reduction of price on linen may ultimately increase its consumption in the East. Already the exports to the Levant have been considerably augmented.

The gross returns of the quantities, and of the declared value of linen manufactures and yarns exported from the United Kingdom during the last year, are very satisfactory. Of woven goods there were 128,780,362 yards, having a value of £3,827,443. The thread, tapes, and small wares were valued at £285,333, and of linen yarns there were 18,518,273 lbs., amounting in value to £935,939, forming a total of £5,048,615 sterling.

Without question, this prospering condition of the trade is attributable to general improvement in manufacturing, and to the consequent reduction in price, which has enabled our manufacturers to compete so successfully with those of other countries. In such a trade progress is essential to vitality. A refusal, or even a hesitation on the part of a manufacturer to adopt an improved process, even at the sacrifice of his old notions, often gives the start to an opponent which costs him years to recover. Disastrous as this is between individuals, it involves far weightier considerations when the competition is between countries. The Irish portion of the linen trade

appears just now to be in a critical state, her means of supply are not equal to the demand; and already we find that foreign countries have re-entered the lists with her in her most prized markets. Two causes have principally effected this. These causes remain, and become more powerful every day. But, cannot they be met? and, if so, why this hesitation? The power-loom dreads not emigration; it flourishes upon "cheap food." The substitution of machinery for hand-labour in the spinning process has long since shown the immense benefits it has conferred on the trade. The requirements of the market, no less than the present peculiar condition of Ireland, call urgently for its application to the loom.

HORTICULTURE.

CHAPTER V.

THE SPECIES AND VARIETIES OF CULTIVATED VEGETABLES.

The subject of the varieties of vegetables is one of the most interesting, and, in a practical point of view, most important, in horticulture. The fact that by culture, modifications of a vegetable may be obtained and perpetuated, is almost the basis of modern gardening. Were we not able to take advantage of it, and procure varieties of the same vegetable, some of which come rapidly to maturity and some slowly, our supply could only be extended over a very short space; whereas, as it is, we can have a very long-continued supply of almost all kinds. But varieties are produced differing from each other in other respects than in maturity. We may, perhaps, be allowed to extract the following passage, bearing upon this subject, from Dr. Lindley Kemp's "Agricultural Physiology:"—

"On the maritime cliffs of England," says this author, "there exists a little plant, with a fusiform root, smooth glaucous leaves, a flower similar to wild mustard, and a saline taste. It is called *Brassica olenacea*. By cultivation, there has been produced from this insignificant and useless plant:—

"1. All the broccolis, or kails, comprising several varieties, all useful as winter food.

"2. All the cabbages that heart. By cultivation we can have them all the year round in a perfectly ripe state; that is to say, by cultivation we have rendered cabbage quite independent of season.

"3. The different kinds of early savoys.

"4. The Brussels sprouts, distinguished by the growth from the axillæ of the leaf stalks of miniature cabbages.

"5. All the cauliflowers and broccolis that do not heart, but produce a large and regular flower, distinguished by containing a larger quantity of albuminous matters than any other vegetable production (excepting mushroom). By farther cultivation, sub-varieties of cauliflowers and broccoli have been produced, so as to furnish a constant supply of flowers all the year round.

"6. The rape, cultivated for its forage leaves and oil-producing seed, and of which several sub-varieties exist, the most important being *Brassica campestris* and *Brassica rapa*.

"7. Swedish turnips.—The production of this plant, cultivated for its nutritious root, is even a more wonderful exemplification of the power of cultivation than any of the preceding. It originated from the *Brassica campestris*.

"8. Yellow and white turnips. These are modifications of the *Brassica rapa*.

"9. Hybrid turnips. These are produced by crossing the yellow or white with the swede.

"10. The kohl rabi. This has the root of the turnip, and the foliage of the kail."*

Unfortunately, however, the greatest confusion, and, indeed, something worse than confusion, prevails in almost all the seed shops with regard to these varieties. It is now perfectly well ascertained that many varieties, or at least what are named varieties, and professedly differing, are actually sold out of the same bag, and not unfrequently, indeed, are charged different prices just according as to the name by which they are asked for. In point of fact, the gardener who desires to be successful, requires as much to know what is false regarding these varieties as what is true. In this chapter it is our aim to state, first, with regard to each particular vegetable, some general particulars regarding its habits and history, then to give, as far as we are able, a statement of the impositions practised regarding its varieties, and lastly, an account of those varieties of it that we believe are really genuine and worthy of attention. We begin with the leguminous plants, and, first of all, with the pea.

* Agricultural Physiology, Animal and Vegetable, p. 236.

LEGUMINOUS PLANTS.

THE PEA.

The pea is the *Pisum sativum* of botanists, so named from its having been a great object of culture in Pisa, a town of Elis. It was called by the older English writers upon horticulture peason, and has attained its present name by dropping the last syllable. It probably did not find its way into England until the reign of Henry VIII., and was a rarity until the latter part of the reign of Elizabeth, since which time it has been cultivated in great abundance.

An immense number of varieties of the pea, so "named," at least, are sold in the seed shops. Most of them profess to sell as distinct sorts—early Kent, early May, Hotspur, Warwick, and double-blossomed frame. All these are one and identical. Perhaps the best name for them would be the last—double-blossomed frame.

Again, Prince Albert's, Racehorse, Emperor, Charlton, (and very often white Prussian,) and single-blossomed frame, are exactly the same, and kept in one bag. Perhaps the best name for all these peas would be Prince Albert's pea.

Richardon's Elipse and Towoodlee are exactly the same pea, although, if asked for, sold and labelled in separate packages as different.

Then blue imperial, scymitar, and Bedman's imperial, are exactly the same, save that in some shops, this pea, if asked for under the name of scymitar, instead of imperial, is, although taken out of the same bag, charged a penny a pound more.

The following are the kinds of peas that should be selected for a garden of the size and kind to which we, in this dissertation, refer:—

1. Single-blossomed frame, or Prince Albert's.

This is suited for the earliest and latest planted crops, because it comes sooner to maturity than the following kinds:—

2. Prussian blue.
3. Imperial green.

Both these, particularly the latter, are very suitable for the main crops, on account of their prolific bearing. In fact, with Prince Albert's and the imperial green, a supply of peas may be obtained for a very long time, and the two are quite sufficient for all ordinary purposes.

THE BROAD BEAN.

The Broad bean was probably introduced into Britain by the Romans, and, except in the extreme north of the island, it has always remained a great favourite, on account of its eating well with bacon, a meat that has now for ages formed a staplo of Anglo-Saxon diet.

A good many varieties of broad beans are sold in the shops, and the way in which some of them are procured is this:—The seeds of Windsor beans are taken, and passed through a riddle. The smaller ones that pass through sell for what they are, Windsor beans. The larger, that will not pass, are arranged into two or three parcels, (if the trouble can be taken; if not, they go into one, and answer to different names, as asked for,) to pass for Taylor's Windsor, new thick-seeded, &c.

Three varieties of broad bean *have* an existence, and deserve a place in the garden.

1. Early long pod.
2. Mazagan.
3. Windsor.

The early long pod comes most rapidly to maturity, and is therefore best suited for the earliest crop. The Windsor is probably the best for a main crop, as being more prolific. The mazagan is more prolific, but not so early as the long pod, and not so late, (by, however, a very little,) but less prolific than the Windsor. But the mazagan would appear of late years to have been falling off.

THE KIDNEY, OR FRENCH BEAN.

This vegetable derives its name of kidney on account of its seed being of a kidney shape, and of French, because it long has been, as it now is, extensively cultivated by our Gallic neighbours. It is by no means of French origin, but a native of the most southern parts of Europe, and is, for this reason, extremely sensitive to cold. It ripens its seed in this country, and its cultivation, both for the purpose of eating it in an unripe state, and for the sake of its ripened seeds or haricots, is by far too little attended to. It is only, however, in the southern part of the island that the ripening of its seeds may be depended upon in ordinary seasons.

Several kinds are kept in the seed shops, but few shops keep more than one kind, and we suspect that scarcely any have more than two.

The following two kinds unquestionably have an existence, and are worthy of culture:—

1. Dutch dwarf.
2. Purple-speckled.

The Dutch dwarf is the earlier of the two, but the latter yields a better crop. It requires, however, to be sticked, and cannot be procured in many seed shops.

French beans, we may observe, were introduced from the Low Countries in the reign of Queen Elizabeth.

SCARLET RUNNERS, OR POLE BEANS.

These have for some time been cultivated on account of their beautiful flowers, but it is only, at least in many localities, for the sake of their immature legumes that they have been grown, which legumes may be used in the same manner, and are as good, as those of the common kidney-bean. Two distinct varieties of the scarlet runner exist.

1. Common scarlet runner.
2. Painted lady.

The latter may be known by the keel of the flower being almost white. We are not aware that any difference, either in early maturity, or in productiveness, has been noticed.

We pass on to the alliaceous plants, foremost among which must be reckoned the onion.

ALLIACEOUS PLANTS.

THE ONION.

The onion used to be called the unio, because its bulb never throws off any offshooots; and from this name of it the common English word, onion, is derived. It is often stated to be a native of Spain, but in all probability the onion was cultivated before Spain was inhabited. In all ages it has enjoyed a high reputation, both as an article of diet, and as a seasoner of other dishes. It is employed in the Peninsula, and other continental countries, in the former capacity, more so than here.

The three varieties of onions, sold in the shops as Deptford, Strasburgh, and Reading, differ in this, that the seedsmen give them different names, but in other respects they are the same, and grown from the same bulbs. Again, between white Spanish onion and white Portuguese, there is not the slightest difference. Tripoli and Giant onions are quite identical, and so are silver-skinned and white pearled.

There are, however, several distinct varieties of onions, but for all practical purposes three will suffice. These are—

1. Strasburgh.
2. Blood-red.
3. James'.

The first and the last are good keepers, and the red marks in the blood-red give it a pleasant appearance. To these we must add, to be used for pickling—

4. Silver-skinned.

THE LEEK.

The leek is a native of Switzerland, but has long been pretty extensively cultivated in every country of Europe. In England it has been grown for a long time, and has been for a dozen of centuries almost the national plant of Wales. All true Welshmen wear it upon them on St. David's-day. They do this in commemoration of a victory, which they obtained over the English in the sixth century, and in which battle those fighting on the Welsh side distinguished themselves from the enemy by wearing leeks.

The custom in many seed shops is to sell the best samples of leek seed as Musselburgh leek seed, and the others by any name it may chance to be asked for. Hence, in buying leek seed, the best plan is to ask for Musselburgh at once. But there used to be a narrow-leaved kind, now nearly and perhaps deservedly extinct.

CHIVES.

The chive is an indigenous plant, and occurs in a wild state about Yorkshire, and other parts of the north of England. It has been gradually disappearing from our gardens, but improperly, inasmuch as it is excellent as an adjunct to spring salads.

It is also used to flavour soups and omelets. There is only one variety of the chive.

GARLIC.

Garlic is more employed in continental than in English cookery, owing, perhaps, to our cooks being ignorant of the proper manner of preparing it. The plant is a native of the south of France, and was introduced into Britain in the reign of Queen Mary. The part used is the root, which consists of many little bulbs, or cloves, as they are called. There is now only one kind of garlic, but there used to be two.

ESCHALOTS.

The eschalot is a native of Palestine, and was brought to Britain in the year 1548. It has a milder flavour than the onion, and comes into use considerably sooner. There are no varieties of the eschalot.

ROCAMBOLE.

The rocambole is a native of Denmark, Sweden, and other northern countries. It was introduced into this country in the sixteenth century, and is occasionally, but very rarely, cultivated for its bulbs, which are thought somewhat milder than those of garlic.

POTATO ONION.

The potato onion is an alliaceous plant, propagated by means of its bulbs, and forming fresh ones underground. It has been known in this country for more than fifty years, but has never been so much cultivated as it ought to be. Its flavour is milder than the common onion, and it comes into use considerably earlier.

ESCULENT ROOTS.

The above are all the alliaceous plants cultivated in this country. The esculent roots next claim our attention. Of these the most important is—

THE POTATO.

The early history of this invaluable root is confused, owing to the word potato originally belonging to the tubers of the convolvulus batata, a plant that will not ripen even in the south of France, but which was, just previous to the introduction of the potato, called by the old writers the potato, and which was cultivated, apparently pretty extensively, in Spain and Italy.

Our potato was brought into Europe by some of the colonists of Sir Walter Raleigh. The first ship that went out to Raleigh's colony of Virginia, did so in 1584, and returned in 1586. It is not known, however, whether Sir Walter

brought it himself on his return, or whether it was sent to him afterwards by Mr. Lane, the governor of Virginia. However this might be, Sir Walter Raleigh was the first man who cultivated it in Europe, and this he did at his estate in Ireland.

The first place in England where potatoes are believed to have been grown, was a place on the coast of Lancashire; some tubers having been found in an Irish ship that was wrecked there. Its culture soon spread, but it was used not as an article of diet, but as a great luxury. Gerarde, who had it in his garden in 1597, under the name of Batata Virginiana, speaks of its roots as a great delicacy; and we learn from another writer of the period, that they were served with sack and sugar, or baked with spices, or sometimes candied.

This state of matters, however, soon passed away, and potatoes began to be cultivated as food, but were held in no esteem. Even Evelyn, writing in 1699, says, "Plant potatoes in your worst ground. Take them up in November for winter spending; there will enough remain for a stock, though ever so exactly gathered." The *Complete Gardener*, by London and Wise, published in 1717, but probably written earlier, makes no mention of potatoes whatever.

The use of potatoes, however, gradually extended until, about the beginning of the present century, they began to be used in part as a substitute for corn. They now form a part of the dietary of every one, and a daily part of the dietary of most persons.

Hundreds of varieties of potatoes have been produced by culture. The following selection comprehends a sufficient number for all practical purposes:—

1. Early ash-leaved kidney.
2. Hopeton early.
3. American early.
4. Fortyfold.
5. Regents.
6. Cups.
7. Orkney reds.

The early ash-leaved kidney is the earliest, but not prolific. A few, however, should be planted to serve as an earliest crop. The Hopeton early is nearly as early and more prolific. The American early and the fortyfold come in in July, and last, if desired, for several months. All these varieties are distinguished by their tubers being fit for use before the haulms have decayed. The tubers of those that come after them in the above list, are not ripe until the haulms are quite decayed. This will probably happen in the beginning of October. The regents are fit for use immediately, but the cups and Orkney reds require to be stored for some months before they are so, and these last-mentioned afford a supply until the ash-leaved early comes in in summer.

The cups used to be considered a very coarse variety, not suited for human food; but, either from the disease or some other cause, they have become very much improved.

JERUSALEM ARTICHOKES.

This plant is a species of sunflower, and a native of Brazil, whence it was procured by the French Canadians, from whom it found its way to Europe. The way in which it has procured its name is extraordinary. Its tubers are the part used, and they are considered to resemble artichoke bottoms, so that part of its name is intelligible enough. The Italians named it gerassole, which means, we believe, "turn with the sun." Two tubers were brought to England in the reign of James I. From these two tubers, all the succeeding ones are descended, and they were called gerassole artichokes. The gardeners, by degrees, corrupted this into Jerusalem artichokes.

Another old name of this plant is Canada potato.

Only one kind of Jerusalem artichoke is known in most of the seed shops; but of late, in some lists, we have noticed the name of a new. Whether this has any peculiarities or not, we do not know.

TURNIPS.

The turnip is one of the oldest of the cultivated vegetables.

A great many of the named varieties of turnip seeds are identical. Thus early snow-ball (which, a list before us says, should be sown in March), and early white stone (which, according to the same authority, should be sown in May), are nevertheless raised from the same bulbs. And yellow Maltese, Altringham, yellow golden ball, and Liverpool yellow, are exactly identical.

The following three varieties have really an existence, and are sufficient for all practical purposes:—

1. Early Dutch.
2. Yellow Maltese.
3. Large Swede.

The early Dutch is suited for the first crop; the yellow Maltese for the second, and for one in autumn; and large Swede for a main crop for storing.

CARROTS.

The carrot grows wild in this country, but the stock from which our present seeds have descended, is said to have been introduced into Kent by the Flemings, in the reign of Queen Elizabeth; and these again are said to have descended from the carrots cultivated in the island of Candia.

Parkinson says, that in his time the ladies wore carrot leaves in place of feathers.

The kinds sold in the shops are early horn, Dutch horn, and French horn, and are either exactly the same, or so nearly identical as to be practically the same. This is true, also, of the long red, orange, and Surrey.

The three following kinds are distinct and useful:—

1. Early horn.
2. Orange.
3. Altringham.

The early horn is suitable for an early crop; the other two for a main crop for storing; but if the land be light, the orange should be fixed upon, as producing, perhaps, the largest crop. If, on the other hand, the land be heavy, it is best to grow the Altringham, inasmuch as carrots of this variety grow with their roots a good deal out of the ground.

PARSNIPS.

The parsnip has been cultivated for a very long time, and used to be, and deservedly, in greater repute than it now is. It is not only useful as an esculent vegetable, but its fermented juice is said to make an excellent wine.

Notwithstanding that many seed lists contain two or three varieties, we believe they are all exactly the same.

RED BEET.

This vegetable derives its name from the resemblance of its seed vessel to the Greek letter β. It was called in France, *beta rave, i. e.*, beta, or β radish, and we have corrupted this into beet root. It is a native of the sea-coast of the south of Europe, and was introduced into this country about three hundred years ago.

Of the common garden red beet, there is, we suppose, only one sort.

THE SKIRRET.

The skirret is a native of China, and has been known in this country for about three centuries. But it is now very little cultivated, although, by the old writers, it is considered one of the best of roots.

Only one kind of it is sold in the seed shops.

It is perhaps proper to mention, that, although skirret seed may be obtained in the principal seed shops, it is so old that it will seldom germinate. At least such has been our own experience.

THE SCORZONERA.

This root is now seldom grown. Its popular name is viper grass. It is a native of Spain, and the adjacent countries. It was brought to this country in 1576. There is only one sort of it, and even this is scarcely ever seen.

THE SALSIFY.

This is another neglected root. It is a somewhat rare indigenous plant, and used to be known by the name of goat's beard. Only one kind of it is cultivated, and that very seldom.

RADISHES.

The radish is a native of China. It was known to Gerard. At first, upon its introduction to this country, it would seem to have been used in a cooked state, but for long it has been esteemed raw as a salad. The three following varieties are amply sufficient:—

1. Spiral-shaped scarlet or salmon radish.
2. Turnip radish.
3. Spanish.

Of these, the first is somewhat earlier, and it and the turnip may afford spring and summer supplies. The Spanish is a hardy kind that may be sown in autumn, and part of the crop lifted and stored, and the rest left in the ground until spring.

SPINACEOUS PLANTS.

From the root plants we may pass on to the spinaceous plants. Of these the type is—

SPINACH.

Spinach has been long cultivated in this country. Its original site is probably either Spain or the north-west of Africa. Two varieties of it exist:—

1. The smooth-seeded.
2. The rough-seeded.

Of these, the first is considered the best for summer use, and the latter for winter; but the former does very well for both seasons.

WHITE BEET.

This is a native of the Peninsula, sometimes grown in this country for its leaves, which are boiled as spinach.

RACH.

This is an inhabitant of Tartary, often grown in France for its leaves, which are boiled, but very seldom seen in this country.

NEW ZEALAND SPINACH.

This is a chenopodium, a half-hardy annual, of which a short notice will be taken when we come to the chapter on the hotbed, and hotbed plants.

SORREL.

This is a species of indigenous vegetable which formerly found a place in every garden, and which was used partly for soups, but principally for forming an accompaniment to boiled veal, under the name of green sauce. In this last capacity it is very good, and it is to be regretted that it is now only to be found in pretty old established gardens.

CABBAGE PLANTS.

The plants belonging to the cabbage tribe now require enumerating. We begin with

THE KAIL.

This is the borecole of many writers, and one of the oldest of the cultivated vegetables. It is so hardy as to withstand any amount of frost, and is, indeed, almost our only fresh winter vegetable. The two following varieties are sufficient for an ordinary garden:—

1. Scotch kail.
2. German greens.

Several sub-varieties of the latter exist, and the former, which is of much larger growth, is every year becoming more and more nearly extinct.

SAVOYS.

This is another winter vegetable, remarkable for the corrugated appearance of its leaves, and which appearance distinguishes it from the cabbage. It is a native of Savoy, and has been cultivated here for about a century and a half. Two varieties may be mentioned; but the first of them is sufficient for any small garden.

1. Dwarf green.
2. Yellow.

BRUSSELS SPROUTS.

This excellent vegetable, like the last mentioned, is in season in winter, and also a native of Savoy. It has, however, been very extensively cultivated in Belgium, and hence its common name, Brussels sprouts. Neither its leaves, as those of the kail, nor its heart, as that of the cabbage or savoy, are eaten, but a number of little sprouts that resemble in appearance miniature savoys, and which arise from the axilla of the leaf stalks. A small bed of these affords a supply from November to March. There are no sub-varieties of them; but it is always better to get Belgian seed, inasmuch as that grown in this country, or from other plants belonging to the cabbage tribe, being seeded in the same garden, are apt to be impure.

RED CABBAGE.

The red cabbage is so named, because its natural blue colour is changed to red by the action of vinegar when it is pickled, this being the only form in which it appears at our tables. Two varieties of it exist.

1. Red Dutch.
2. Red dwarf.

The only difference between the two exists, probably, in the size, although the latter is, by some, considered the most delicate.

WHITE CABBAGE.

White cabbages have been cultivated from time immemorial. The state of our knowledge regarding the varieties of them, and of the succeeding vegetable (cauliflowers) is most confused. According to some of the seedsmen's lists, there are several hundreds. Of these many have no existence, and many more are merely different names for the same. The following are real varieties, and sufficient in number to afford a supply over a long space:—

1. M'Ewans.
2. Early dwarfs.
3. York.
4. Drumhead.

These are inserted in the order in which they come to maturity, and from these four a supply of cabbages may be obtained from May to Christmas.

CAULIFLOWERS AND BROCCOLIS.

We put these two together, because they are one and the same. The cauliflower was introduced into England from the island of Cyprus in 1694, and to a hardy variety the name of broccoli was given. Many seed lists give the names of numerous varieties of both; but, we suspect, that the best plan is simply to ask for cauliflower and broccoli seed.

ASPARIGINOUS PLANTS.

We proceed to consider the asparaginous plants and their varieties, beginning with—

ASPARAGUS.

Asparagus is an indigenous plant, but growing only in a few localities near the sea shore. It has been cultivated, at any rate, since the time of the Romans. We think we may consider the two following as real varieties, and that the latter is the better:—

1. Red topped.
2. Green topped.

The other varieties put down in seed lists have not, we believe, a separate existence.

SEA KAIL.

Sea kail is an indigenous plant, growing on the sea shore; and the inhabitants of Dublin, and of parts of the southern coast of England, have been, from time immemorial, in the habit of watching the young shoots when first pushing themselves through the sand, cutting them in their blanched state, and cooking them. It would appear, too, that for a long period sea kail has been cultivated, in isolated cases, in gardens; but its introduction into the list of cultivated plants is owing to Dr. Lettrome, who, rather less than a century ago, wrote a little

pamphlet regarding it. While one of the easiest grown, it is one of the most delicious of vegetables, and it yields its supply at a time when scarcely anything else fresh is to be had. There is no difficulty in having it ready for beginning to be cut by Christmas. There is only one sort of it.

ARTICHOKE.

The artichoke is an African plant; but was brought here from Italy in the reign of Henry VIII. In this country, the immature heads are boiled; but, on the continent, the artichoke is used in a variety of ways. There are two varieties.

1. Globe.
2. French.

The globe has a globular head of a purplish tint, and the scales a good deal turned in at the top; while the French has an oval greenish head, and the scales not much turned in at the top. The French is the hardier kind.

THE CARDOON.

The cardoon was brought from Candia in 1658. It resembles the artichoke, but is much taller, sometimes attaining the height of four feet. It is used in a variety of forms abroad; but here, when it is used at all, which is seldom, it is the blanched stalks of the inner leaves that the cook employs.

RAMPION.

This is another plant very seldom cultivated, the roots of which may be used either raw, as a salad, or cooked, like asparagus. There are two or three other plants, as alisander, &c., belonging to this division, which used to be cultivated, but are now scarcely ever seen.

SALAD PLANTS.

THE LETTUCE.

It is not known from what country the lettuce was introduced, nor where it is native. It is believed that one variety of it came from the island of Cos. It found its way to England in the reign of Queen Elizabeth, and is now the most extensively cultivated of our salads. Two distinct kinds of it are known: the cos, or upright, and the cabbage, or roundheaded. The shops profess to keep a great many varieties of each kind; but, in general, it is sufficient to ask simply for cos or cabbage lettuce seed. For a late crop, however, a decided variety, called black-seeded cos, is the best.

THE ENDIVE.

The endive is a Chinese plant, and was introduced into England in the reign of Edward VI. It is very hardy, and affords us an excellent winter salad. The two following varieties are sufficient:—

1. Green curled.
2. White curled.

The first is the hardier, and must, therefore, be taken for the winter crop; while the second is remarkable for taking a short time to blanch, but it is not hardy. It is, therefore, desirable for an autumnal crop.

CHICORY, OR SICCORY.

This is now extensively grown for the sake of its root, which is kiln-dried and mixed with coffee; but abroad, and to a small extent in this country, it is grown as a salad, and blanched like endive.

CELERY.

This is the winter celery *par excellence* of this country, and is also much used for flavouring soups. It is an indigenous plant, but very much altered by culture. The three following varieties are distinct:—

1. Dwarf Italian, or hollow.
2. Red solid-stalked, or Manchester.
3. White do.

The first of these may very well be discarded. We have mentioned it, however, because it is rather earlier. There is also a turnip-rooted variety called celeriac, only used for soups.

MUSTARD.

Mustard, grown as a small salad, is the white mustard of botanists. The black mustard is grown for the purpose of making flour of mustard.

CRESS.

This small salad has been in use in this country for some three centuries. The best variety (best only from its appearance) is the curled leaved, when this can be got. Besides mustard and cress, a few other plants are occasionally used as small salads, but they are so unimportant as not to require even enumerating.

POT-HERBS.

We proceed to the pot-herb and garnishings, and begin with

PARSLEY.

This is a Sardinian plant, and was introduced into this country in 1548. The variety with curled leaves should always be used, to guard against it being confounded with the poisonous weed called fool's parsley.

TARRAGON.

This is a Siberian plant, but has been cultivated in this country for the three past centuries. Its principal use is to flavour vinegar for a fish sauce; but the leaves are sometimes eaten with beefsteaks, put into salads and soups, and also pickled. There is only one kind of it.

FENNEL.

This beautiful plant is principally used for garnishing. Its leaves form part of several fish sauces, and it is sometimes used as a salad. A variety of it, called finochio, is blanched, and used as a salad, and also stewed.

HORSERADISH.

Horseradish is a native plant. It has long been valued by the herbalists; but it was not until the time of Queen Elizabeth that it was used along with roast beef, and ever since that time it has been associated with that national dish. There is only one kind of it.

INDIAN CRESS, OR NASTURTIUM.

This plant came from Peru. It is cultivated mainly for its flowers, but also for its berries, which are used in place of capers, and for its leaves, which are employed as garnishings, particularly by candle-light. There are two varieties, the larger and the smaller.

MARIGOLD.

This is now only grown as a flower; but, we believe, the old custom of putting marigold flowers into soup is still kept up at Christ Church Hospital. In Holland they are still extensively used in this last-mentioned manner.

BORAGE.

This is now only used as an ingredient in "cool tankard." Our ancestors, however, thought that borage had the power of driving away sorrow. If so, it is a pity it is not more cultivated.

SWEET HERBS.

Another of the sections under which the cultivated vegetables are divided by systematic writers, is that of the sweet herbs, and this now demands our attention. The first upon our list is—

THYME.

This plant has been in use for time immemorial, for flavouring stuffings, soups, &c. Long ago it was much used in domestic medicine. Two distinct kinds are cultivated:—

1. Common thyme.
2. Lemon thyme.

SAGE.

This is a native of the south of Europe, but has long been domesticated in our gardens. Our ancestors believed that it had the power of strengthening the memory, and, indeed, many other characteristics. We believe it is now mainly used for the stuffing of ducks. Sage cheese may even yet, however, sometimes be seen, and if the memory of a single taste, a good many years ago, may be relied upon, it is rather pleasant. Three or four varieties are enumerated, but we may fancy that called common or red is the best.

CLARY.

This is a Syrian herb, which is now almost entirely neglected, but which we mention here, because its flowers are said to be used for making a wine that very much resembled Frontignac. Surely sugar must have been added.

MINT.

There are two kinds of mint grown in our gardens—green or spearmint, which, with vinegar and sugar, forms the appropriate sauce for lamb; and peppermint, employed for making a cordial water, and for flavouring a particular kind of sweetmeat.

MARJORAM.

Marjoram is a native of Greece, but has dwelt in our gardens for three centuries. When it is used at all, it is for flavouring soups. There is more than one kind of it, but it may here be sufficient to mention the name of the commonest—pot marjoram.

SAVORY.

This is even a still more neglected plant than the last, but its leaves are useful for boiling (in small quantities) with peas and beans.

BASIL.

We introduce this, because, although seldom grown in this country, it is considered by the French cook as indispensable for flavouring soups, &c. The large-leaved is the right kind.

ROSEMARY.

This aromatic shrub is a native of Greece. It is sometimes used for throwing upon the coffins of young maidens before the earth is thrown in, and for stirring beer.

LAVENDER.

This plant is rarely used now in cooking, but extensively for the scent of its seeds.

TANSY

Is used for flavouring pancakes, and is perhaps unjustly neglected.

MISCELLANEOUS.

Although, in the above divisions, we may have more than once included plants that scarcely belonged to them; there are still a number of vegetables to be noticed that are not included under any of the above heads. We now notice these, and begin with—

RHUBARB.

Several varieties of rhubarb have been cultivated for the sake of their leaf-stalks, which are peeled, cut down, and formed into pies, &c., and also now much used for making British champagne; but of late an improved variety, called Myatt's Victoria, has completely eclipsed the others.

GOURD.

Gourds, or pumpkins, are the melons of the old writers, the modern melon being by them denominated the musk melon. They are a very ornamental plant, and the gourd itself is used for thickening soups, simply boiled with butter, and in a pie with pears.

VEGETABLE MARROW.

This plant is of Persian origin, and of comparatively recent introduction into this country; its properties are the same as those of the gourd. There are now several sub-varieties of them, but we are not aware if they have received any distinct names.

ANGELICA.

This plant is a native of the north of Europe. Its stalks were formerly blanched and eaten as celery. Now, however, they are candied by the confectioner, and sold in that state.

CARAWAY.

A native plant, cultivated for its seeds. Formerly its roots were boiled and eaten.

CAMOMILE.

This is a native plant, cultivated in every garden for the sake of its flowers, the infusion of which is principally used as a fermentation. It is also employed to assist vomiting in bilious attacks. There is a double kind, which is not so good as the single.

RUE.

This shrub, a native of the south of Europe, is very unjustly neglected. It is very useful in flatulent colic, and in hysteria. Tea of the fresh leaves should be made, an ounce of the fresh leaves being infused in a pint of boiling water. The dose is two table-spoonfuls.

HYSSOP.

Another aromatic plant, seldom used, but occasionally grown.

ELECAMPANE.

A native plant, the root of which is sometimes candied, and used as a stomachic.

BALM.

This is a Swiss plant, and the tea of it is occasionally used as an agreeable drink in febrile affections.

TOMATO, OR LOVE APPLE.

The tomato is a native of South America, and was brought to Europe by the Spaniards. Its ripe fruit yields one of the best sauces for meat that we possess. It is also cooked by itself. There are two or three varieties, but the old original red is the only good one.

EGG PLANT.

The egg plant will only occasionally ripen in the open air in this country. It is used for the same purposes as the tomato.

CUCUMBER.

The cucumber has been cultivated at least three thousand years, and Moses mentions it as abounding in Egypt in his time. Perhaps the best varieties are:—

1. Early long prickly.
2. Early short prickly.
3. Prize-fighter.

MUSHROOMS.

These are well-known native vegetables, but, as some poisonous ones resemble the wholesome kinds, it is always better to cultivate them artificially. The kind always so artificially grown, is the Agaricus campestris.

Such are the principal plants grown in our gardens. It is probable that one or two wild species might advantageously be introduced.

The common nettle, for example, would afford young shoots in February, that make an excellent substitute for spinach. Then the wild plant that grows in hedge bottoms, the Erysimum alliaria, or Jack by the hedge, is said, when boiled, to form an excellent accompaniment to boiled mutton. The Orchis morio might be cultivated for the sake of making the old-fashioned beverage, saloop. If necessary, many others might be mentioned.

PORTABLE STEAM-ENGINE, WITH BOILER COMPLETE.

By M. Rennes, Manufacturer, Paris.

Much attention has been given, especially for some years past, to the construction of portable steam-engines, occupying little space, and such as may be furnished at a cost admitting of their application to the smallest industrial operations. At the Great Exhibition, for instance, there was an extensive display of small locomotive engines, especially intended for agricultural purposes.

In France, as in England, several makers have attempted to construct small machines, working at considerably higher speeds than those generally adopted, with the view of transmitting the movement in a simpler manner, and thus of rendering them lighter and more portable.

For example, M. Fland, at Paris, is engaged in the construc-

tion of small engines of a high speed, which do not make less than from five to six hundred turns per minute, and which, from that circumstance alone, are reduced to exceedingly small proportions. M. Fland sent one of these engines to the Great Exhibition, to drive the improved mechanical saw of M. Santreuil of Fécamp, for which he obtained the prize-medal.

MM. Thomas and Laurens have likewise applied machines of a high speed to various manufacturing operations. But these and other engines, hitherto constructed on this principle, have generally been formed without their boilers attached.

M. Rouffet of Paris, and Mr. Trevithick of London, have constructed engines both fixed and portable, which are mounted directly over their boilers, or are made in one piece with them. The new engines constructed by M. Rennes are of this description.

Fig. 1 of the annexed design is an exterior elevation of the whole apparatus, including the boiler on which the engine is mounted.

Fig. 2 is a transverse section made by the axis of the engine, and in a plane perpendicular to that of the preceding figure.

M. Rennes' system fulfils these essential conditions—it is of great simplicity, very economical in construction, and occupies very little space.

This engine, including its boiler, is not more cumbrous than any other piece of furniture; it is as easily put in its place as an ordinary stove, and may, at the same time, in certain cases, very well serve the purpose of that piece of apparatus.

It will be seen from the figures that this machine is mounted on the upper plate or cover, A, of the boiler, E, from which the

Fig. 1.

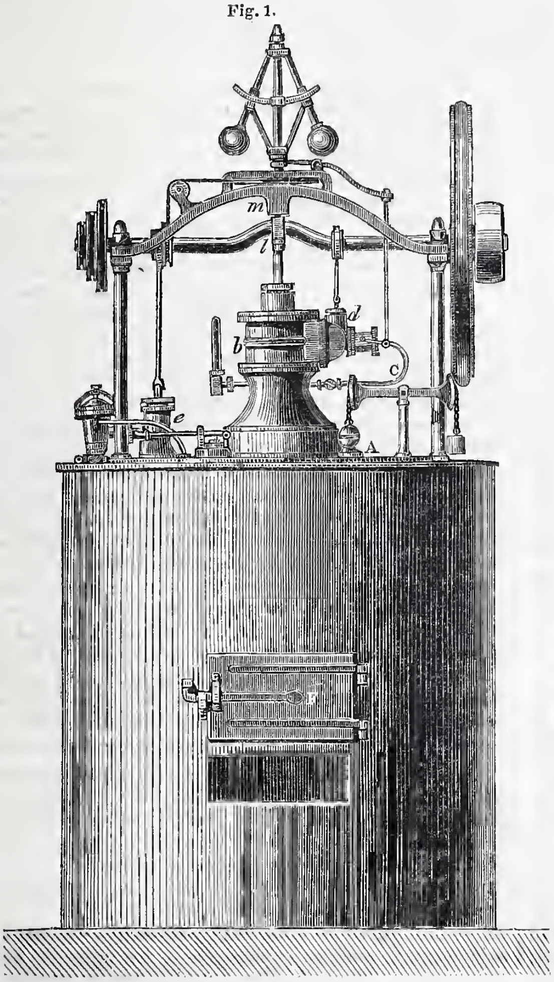
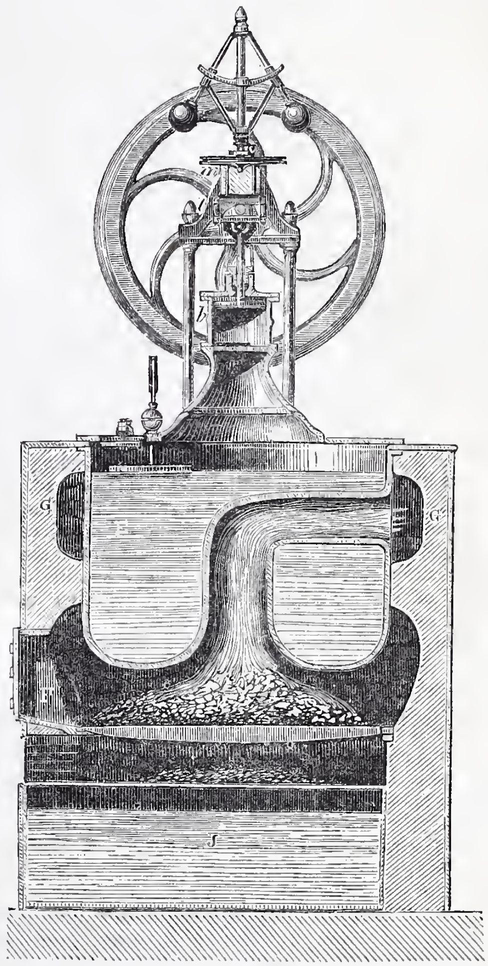


Fig. 2.



Scale 1-10th.

steam is immediately delivered into the cylinder, *b*, by the pipe which is fitted to the distributing apparatus, *d*, cast of one piece with the cylinder.

The maker considers that this arrangement allows of obtaining in the cylinder a pressure almost equal to that of the boiler, because of their close proximity, and thus of effecting a considerable saving in fuel by avoiding the loss of heat. and consequent diminution of pressure.

The boiler, E, placed under the engine, is of the utmost simplicity of construction. Its furnace is placed within the boiler itself, in such a manner as to take advantage of the whole of the heat produced. The smoke, on issuing from the furnace, traverses the boiler by two passages, G, which open out from the furnace, and meet again in the common chimney. This chimney may be a simple stove-pipe for a machine of small power, and may thus be employed, when required, to heat the workshop in which the machine is erected.

The whole of the apparatus, including the boiler, rests on a basement or pile of brick, covered with an iron plate, and under the fire-place is formed a cistern, J, from which the machine pumps water to supply the boiler.

It will thus be seen that such a machine, constructed of a power ranging from that of one man to two horses, is capable of driving a working-tool or a small manufactory, and may be put up, removed, or shifted from one place to another, without any previous building arrangements—a circumstance which

cannot be too highly appreciated, since it permits the realizing of a marked economy in the first expenses of the establishment.

FARADAY'S SPECULATION ON MATTER AND ELECTRIC CONDUCTION EXAMINED.

ARTICLE II.

12. From the exposition contained in the preceding chapter, it must be apparent that a satisfactory explanation of the nature of electrical conduction in bodies may be afforded, without alteration of our previous notions of the nature of matter. It only becomes necessary to reject that part of the atomic hypothesis which regards the space existing between the constituent particles of bodies, as EMPTY; and, being empty, as exercising a NECESSARY influence upon their conducting and insulating powers. If we suppose the interstitial spaces to be empty, or absolute voids, it is clear from what has been previously stated, that we must abandon all notion of those spaces exerting any influence whatever; but if, on the contrary, we suppose them to be occupied by a something, however ethereal in its nature, as we most unquestionably do, it then becomes a question, in what degree that *something* influences the electrical conducting power of each body, or whether it exercises any influence at all. Now our belief is, that if the principle which so occupies those intervals be identical with CALORIC, it *does* exercise an influence; and our strong presumption is, that even though it be *not* caloric, still electrical conduction is effected thereby, as also, in that case, the conduction of heat; but inasmuch as we know that some substances possessing interstitial spaces are *conductors*, and others *insulators*, we must, under such circumstances, take it for granted that the subtile principle occupying those spaces is itself influenced by certain peculiarities in the modes of arrangement of the constituent particles of those substances which, by altering the dimensions of the containing spaces, or by other means, modify and influence its conducting powers.

13. That the particles constituting different bodies are arranged in different forms, is amply demonstrated in those substances in which crystallization occurs: in fact, it is this diversity of arrangement *within* the mass, that gives to crystallized bodies their beautiful variety of form *without;* but we may go farther, and assert that diversity of molecular arrangement is not confined to crystalline forms, but may be demonstrated to exist in all other forms of matter. For instance, when the action of the vital principle ceases to be opposed to the influence of other forces in organic substances, extensive changes immediately occur in the arrangement and constitution of the particles composing those substances; and it will be found, that the *slightest* contact with atmospheric air, or the least chemical disturbance, will cause a transposition of the atoms constituting each particle, and this, *by decomposition,* produces new substances. These changes of atomic arrangements, presenting themselves under different circumstances, are distinguished by such terms as *putrefaction, fermentation,* and *decay;* and by these changes the most complex organic particles are reduced into particles of less complex constitution; thus, if the liquid called *Aldehyde,* which is easily mixed with water, is extremely volatile, and boils at 70° Fahr., be hermetically sealed up in a bottle, and the atmospheric air as carefully as possible excluded, it will be found that the minute quantity of air that got into the bottle with the liquid, will suffice to produce an extraordinary change in its constituent particles; for its attraction for the oxygen of this *minute* measure of air is such, that in the course of a few days not a particle of *Aldehyde* will be discoverable in the vessel; but, in its stead, a liquid will be found, which will *not* mix with water, but floats upon its surface, whose boiling point is more than 100° Fahr. above that of the original fluid, which has lost its attraction for oxygen, and which cannot be converted into acetic acid. Notwithstanding, however, these essential differences in its properties, the composition of the two liquids is the same—the particles constituting each are formed of the *same* elements in the *same* proportion; but, in the new compound, these particles are *more contiguous,* and are *differently arranged.* Thus it appears that the new bodies formed by the different processes of decomposition owe their existence to the different modes of arrangement, and the greater or less contiguity not only of the elementary atoms constituting the particles, but also of the particles themselves; and that in this way the proportions of the constituent elements being the same, bodies differing totally in nature, properties, and external character, may result,—some of which will be *good,* and some *bad* conductors of the electric principle.

14. But chemical disturbance and contact with air are not the only causes of these extraordinary transformations in organic bodies; for it is now well known that *heat,* whether it be the occupying principle of the interstitial spaces, or whether it be not, exercises an important influence in these changes, regulating the atomic constitution of the molecules or particles in like manner as it does in *inorganic* compounds. Thus, when the saccharine juices of beet roots and other vegetables are fermented at common temperatures, the resulting produce is the same as that of the grape, namely, carbonic acid and alcohol; but at the temperature of from 100° to 120°, *no alcohol is formed;* but we shall find, instead thereof, *lactic acid, mannite,* and *gum.* In like manner, the chief product of the decomposition of the sugar of milk, at common temperatures, is lactic acid; but at a more elevated temperature, this acid gives place to a *spirituous* fluid which, on distillation, produces a pure brandy. According to *Liebig,* that constituent of bitter almonds, called *Amygdaline,* when dissolved in water and mixed with milk of almonds, is almost instantly decomposed; and that aggregate of elementary atoms constituting the *Amygdaline* molecule, which is a group of 90 atoms, becomes resolved into the less complex molecules, constituting hydrocyanic acid, volatile oil of bitter almonds, sugar, formic acid, and water. In other words, the amygdaline molecule is formed from the elements of all these substances combined. This is an example of the disturbance of the equilibrium of a number of atoms grouped into a single molecule, by the *fermentative* process, which calls into play *new* affinities, thus developing *new* compounds, by *new* arrangements of those atoms.

15. Now, although some of the previous considerations might lead many to conclude that the interstitial spaces of bodies, whether occupied by a subtile ether or not, exercise *no* influence on the conducting powers of these bodies, but that the varying degrees of conduction may be satisfactorily explained by the diversity of molecular arrangements in substances, we cannot, after meditation upon the various phases of electrical conduction, reconcile ourselves to the sufficiency of such an explanation of the apparent anomalies of insulation and conduction. But although our views carry us to the recognition of an extremely subtile and, *at present,* imponderable ethereal fluid, filling the interstices between the molecules or particles of all kinds of matter—whose existence its very nature defies our present powers to prove—though the presumptive evidences in its favour, derived from analogous properties and effects of certain perceptible forms of matter, are so strong as to force upon the mind a conviction of its presence; still, one thing is quite clear, namely, that the recognition of such a principle, while it explains satisfactorily all that we want to have explained, does not force our conceptions of natural agencies beyond the limits of material analogies. In other words, it maintains the boundaries between the comprehensible and the incomprehensible: confining our conceptions to the existence of something *material,* too light to be weighed by our most delicate

instruments, *but still having weight*; and too *spiritual* to be imprisoned within our least permeable vessels, *but still having substance*.

16. It is essentially requisite for the proper comprehension of our views, to bear in mind that we have demonstrated space, when *taken by itself* and regarded as empty, to have no influence upon electrical conduction or insulation; but, when taken *not by itself* and regarded as occupied by one or more subtile imperceptible fluids, to exercise a decided influence upon the electrical conducting powers of matter. Looking at the interstitial spaces of bodies in this light, we can understand why lead, which has *greater* density than silver, should have *worse* conducting power, though its spaces are less—and why the same metal which has *less* density than platinum or gold, should have worse conducting power, though its spaces are *greater*.

17. For, assuming the ether, taken by itself, to offer no opposition to the passage of an electric current, but rather to assist its progress, we can easily conceive *that* ether, when in combination or contact with the constituent particles or molecules of different bodies, to be possessed of different properties, which properties are in some cases favourable and in others unfavourable to electrical conduction. Thus, we can understand that the condition of the particles of lead when surrounded, or nearly so, by the *spacial* ether, is strongly positive, and that this *plus* state offers resistance to a *plus* current, and thus renders the metal a bad conductor; and also, that the condition of the particles of zinc so encompassed is highly positive; but that, inasmuch as its density is less than that of lead, its spacial dimensions are greater; and as its conducting power for heat is double that of lead, there is *less* resistance, although zinc also ranks as a bad conductor. If we consider gold, whose density is considerably greater than either of the preceding metals, we shall find that its *plus* condition diminishes with the diminution of the spacial ether, and that therefore its particles are *highly negative*, and consequently present but *slight* resistance to the passage of the positive current; for which reason gold stands high in the class of good conductors. In silver, the density is little more than half that of gold; therefore we must suppose the spacial ether to be so much more in quantity than that of gold, as to render the condition of silver highly positive. This, however, is not the case, for silver is highly negative and first in the class of good conductors; but we shall perceive, on inspection of the table in the preceding chapter, that its *specific heat* is *nearly double that of gold*; but, as heat, if a subtile fluid, must also occupy space, the enlarged spaces of silver need not be occupied by the ether *alone*, and therefore the quantity combined or in contact with the particles of the silver may be supposed to be no more than that contained in gold; and thus we find an intelligible reason for the *highly negative* condition of silver.

18. The same reasoning will apply to copper, whose density is less than that of silver, and its pores or spaces of course more open; but copper is also an excellent conductor, and is *highly negative;* however, the contained ether need not be more than that of gold; for in copper, the specific heat is one-third higher than that of silver, and it is therefore adequate to occupy that part of the spaces unfilled by the ethereal principle. In the case of zinc, which, as we have before stated, is a *highly positive* metal, the spaces are greater than in copper or silver; and therefore, although the specific heat is the same as that of copper, there is additional room for the larger quantity of the ether which in our view is always requisite for the preservation of a plus electrical condition. In like manner, the density of platinum being highest of all the metals, its pores are proportionally *small*, and therefore its negative powers are *high;* but it is *not* a good conductor, the reason of which may be easily explained when we consider that its conducting power for heat is nearly one-third *less* than that of gold, *while its proportion of specific heat is the same.* We therefore at once see, that to the peculiar mode of arrangement of the particles of the platinum, their close aggregation, and the consequent immense force by which they are held together, is owing the resistance presented to the passage of heat, and the consequent resistance to the transmission of electricity. It may here be observed, that in all the *other* metals which are *highly negative,* and at the same time good electrical conductors—for instance, silver, copper, gold, and palladium—the conducting power for heat is nearly three times that of the *plus* metals, which are *all* bad conductors.

19. It will be observed that we admit the possibility of heat, which we take to be an extremely subtile fluid, occupying a portion of the interstitial spaces in common with the homogeneous ether. It appears extremely probable that such is the case; and there is assuredly no great difficulty in bringing this supposition within our comprehension, and believing that if one *so-called* imponderable subtile fluid exists, so may another possessing opposite properties and powers. The energies of heat are developed in various ways, and surely it is easier to believe in the substantiality of such a powerful agent, than to endeavour to suppose it a consequence of vibratory movements of particles. Some of the ablest modern philosophers assert their profound belief in the materiality of heat; and we do no more than give it space to occupy. We must, however, be guarded in our opinion of its *partly* occupying those particular spaces in bodies *also* containing the ethereal principle; for it is not improbable that heat may occupy the spaces between the atoms constituting the particles of each substance, while the *ether* is restricted to the spaces formed by the aggregation of the particles themselves in the constitution of bodies; which latter spaces we may suppose to have greater dimensions than those *within* the particles. Thus, each imponderable fluid would have its proper receptacle; and upon the relative size and proportions of each set of receptacles, may depend that diversity in the properties and condition of substances of which we have presented a tabular view to the reader, in the case of the metals. Such views are quite in accordance with our previous arguments.

(To be continued.)

CHEMISTRY OF ORGANIC NATURE.

CHAPTER IV.

THE ANIMAL KINGDOM.—(Continued.)

CHYMIFICATION OR PROPER DIGESTION.

So soon as the food is introduced into the stomach, it appears to have the power of stimulating the contents of that organ, and producing a copious secretion of fluid. In this way the mass becomes still more dilute, and after the lapse of some time, varying according to the nature of the food, the greater portion is partially dissolved or finely divided, and assumes a liquid aspect; this fluid is termed *chyme*. It has long been an anxious subject of inquiry among physiologists, to determine the nature of the influence by which this solution is effected; water alone is not capable of dissolving either vegetable or animal matter; we must therefore seek for some more energetic medium for producing such a powerful effect. Saliva, it has been observed, in contact with sugar, converts that substance into lactic acid, or the acid of milk; and it has been found, that in diabetes, a disease where the vegetable food is changed into sugar, the whole of the latter is gradually converted out of the body into lactic acid. We have, therefore, from this fact, the explanation of a simple means by which one acid may be produced. It has been inferred from some experiments that, during digestion, free muriatic acid is present in the stomach; the mode of determining this point was by a negative experiment. The free acid was not obtained in an isolated state; and it has been shown that this would be necessary, because, by the the method of experimenting, a portion of common salt contained in the stomach might have been decomposed. This view has, however, received some degree of confirmation

from the experiments of Eberle, who has succeeded in dissolving or digesting coagulated albumen, by means of dilute muriatic acid retained for some time in contact with the internal coat of the stomach of an animal. Dr Beaumont has also shown, that the fluid part of the contents of the stomach during digestion is acid; and that if a portion of the fluid part be placed in a wine glass along with a masticated piece of beef, the latter will be dissolved or digested as rapidly as if it were placed in the stomach, provided it were kept at the same temperature as that to which it is exposed in the stomach, or about 98°. The observation of Schultz, however, would seem to prove, that no muriatic acid is contained in the stomachs of herbivorous animals during digestion; and as this process appears to be precisely analogous in all classes of mammalia, the conclusion deducible would appear to militate against the muriatic acid theory. It is certain that the acid present is exceedingly dilute, and the question remains for solution, is lactic acid, or any other substance of this class, sufficient for the purpose?

The view generally entertained, till within a late period, consisted in supposing that when the masticated food reached the stomach an irritating effect was produced—similar, perhaps, to what we observe when we touch the eye, and an analogous result occurs, viz. the excretion of a large quantity of acid liquor from the walls of the stomach. It was further held, that the muriatic acid, to which the liquid portion of the contents of the stomach, or *gastric juice* as it has been called, owed its acidity, by acting upon the albuminous part of the coats of the stomach, formed a new soluble substance called *pepsin,* which possessed the remarkable power of increasing the solvent action of the acid. By this theory, it was considered that digestion is a true solution of the food, which was thus rendered capable of transuding through the coats of those vessels that have been set apart for its preparation previous to its conversion into that important animal fluid, the blood.

New Views of Digestion.—From some experiments made nine years ago (*Proceedings of the Philosophical Society of Glasgow, 13th March,* 1844), it would appear more probable, that the food is not dissolved in the stomach, but is only finely divided, and passed in minute though solid particles directly through the coats of the blood-vessels into the current of blood. This observation has arisen from the following circumstance:—Most persons are aware that blood is a red fluid, homogeneous in its appearance when drawn from an animal, and somewhat warm; and that, when allowed to stand, it separates into a watery portion, the *serum,* and into a clot or red mass, over which the fluid floats. This fluid, as hitherto observed, is almost always clear-amber coloured, from which no deposit takes place, even after standing for some days in cold weather. Now, it was noticed long ago that healthy females, in a delicate situation, who sometimes, in the lower ranks of life, give way to a prejudice, and get themselves frequently bled, often have a white or milky serum, in place of a clear liquid, in their blood. It was thus rendered probable that this condition of the blood might be perfectly consistent with the best health. It was necessary, however, to discover the cause by experiment.

Accordingly, a strong healthy young man, to whom a good dinner was an equivalent for the loss of a few ounces of blood, was easily prevailed upon to submit to the following regimen and treatment. He had no breakfast, and at four o'clock had for dinner one pound of beefsteak, half-a-pound of bread, sixteen liquid ounces of brown soup, and half-a-bottle of porter. Three ounces of blood were then taken from a vein in the arm at three different periods: the first time, half-an-hour after the meal; the second time, an hour and forty minutes after it; and the last time, next morning at eight o'clock, or sixteen hours after the meal, no food having been taken in the interval. The blood as it issued from the vein had the usual appearance, and the serum which separated from it was about the same in quantity each time. The first time, the serum was whitish and turbid; the second time, it was like whey; while the third time, it was perfectly limpid. The crassamentum or clot, on the first occasion, exhibited nothing peculiar; while on the last, it was covered with a transparent fibrinous crust, beautifully interspersed with white dots.

As it might be supposed that this young man's blood was white before he took dinner, the two following trials were made to obviate that objection.

A vigorous man of about 35 years of age, after fasting nineteen hours, had for dinner, twenty ounces of beefsteak, sixteen liquid ounces of brown soup, and eight ounces of bread. He was bled immediately before his meal, and three times after it, two ounces of blood being taken away each time. The serum obtained from the first bleeding before the meal was perfectly limpid; the serum from the second bleeding, three hours and fifteen minutes after the meal, was turbid; the serum from the third bleeding, eight hours and fifteen minutes after the meal, was still thicker; while that from the last bleeding, eighteen hours after the meal, was again quite limpid, although some supper had been eaten in the interval.

The young man first mentioned, after fasting eighteen hours, dined upon sixteen ounces of brown soup, four ounces of bread, eight ounces of potatoes, twenty ounces of beefsteak, and sixteen ounces of London porter, and fasted eighteen hours after the meal. He had blood taken from his arm four times to the extent of two ounces each time. The serum of the blood first taken, immediately before the meal, was of an amber yellow, and quite transparent; the serum from the second bleeding, two hours and ten minutes after the meal, was turbid; the serum from the third bleeding, eight hours after the meal, was exactly of the colour of water gruel, and quite opaque; the serum of the blood last taken, eighteen hours after the meal, was still turbid, its limpidity not having been, as after his usual fare, restored by an eighteen hours' fast.

In neither of the two last cases did the blood, as it issued from the arm, present white streaks or anything else unusual. The crassamentum of the blood drawn before the meal, was in both cases of the usual red colour on the surface, as also that drawn first after the meal in the last case; but in all the other instances it exhibited the same *pellucid fibrinous crust* already described, although not dotted in the same remarkable way. We can scarcely avoid the conclusion that this pellucid crust is connected with finished digestion, when we reflect that out of nine bleedings practised within eighteen hours after a very full meal, this crust was observed on every occasion, if we except those in which the blood was drawn within three hours and a quarter of the period of taking the meal.

These observations appear to leave no doubt as to the origin of the white colour of the serum of the blood. When a healthy man is bled fasting, the serum is of a transparent yellow colour, like light sherry wine, varying in the depth of the yellow tint, but always perfectly clear. In about half-an-hour after taking food, the serum becomes turbid; the discoloration increases during several hours, till it attains its maximum; after which the serum becomes again gradually clearer, till its limpidity is perfectly restored. The period at which the discoloration is greatest, and the length of time during which it continues, must depend mainly on the quantity of food taken, but also in some degree on its quality, as some kinds of food are digested more readily than others. It may, however, be stated, so far as the observations I have made enable us to judge, that after a full meal of different kinds of food, the discoloration is greatest about six or eight hours after the repast, and that probably somewhat more than an equal period elapses before the serum regains its limpidity. The differences of colour, which are considerable, probably depend on the different substances digested; and it is interesting in this point of view to remark, that the colour varies in the successive bleedings after the same meal, as if the different alimentary principles produced different kinds of discoloration, and entered the blood-vessels at different periods.

It may be inferred from the facts narrated, that the food

digested in the stomach and bowels is introduced into the system, and mingled with the blood in a crude or half-assimilated state, and that it requires to undergo a second digestion within the blood-vessels before it is perfectly assimilated. It is a highly interesting inquiry, by what means this second digestion in the blood-vessels is effected. The analogy of plants would indicate the lungs as being the principal agents; for we find the crude sap brought by the sap-vessels to the leaves or organs of respiration, converted by them into the *succus proprius*, or true blood of the plant.

The respiratory act in man is not confined to the lungs, but takes place in every part of the system to which the absorbed oxygen is carried by the arterial blood; but it is a confirmation of the view just suggested, that at no time do we feel the want of free air more severely than soon after a full meal. In all probability, however, the process of assimilation in the animal body is more complicated than in plants, and may require the co-operation of various organs.

It is at present a matter of doubt among physiologists whether the primary nutritious liquid prepared by the digestive organs is introduced into the blood through the lacteals, or through the branches of the portal vein. It cannot, however, be doubted, that when the nutritious matter is first absorbed, it is in the liquid state. It is remarkable, therefore, that it should be found afterwards in the blood as a precipitate, or in the solid state. It may, however, be readily conceived how this effect will be produced, when we reflect that the food if dissolved in the stomach by an acid liquid which is absorbed by the vein of the stomach will, on mingling with the blood, be at once rendered alkaline, and will therefore let fall whatever substances its acidity enabled it to dissolve. This reasoning, however, is no longer applicable if we suppose the white matter of the blood to be derived from the admixture with it of the alkaline chyle. A different explanation has been suggested. It is supposed that the white matter of the serum might be soluble in it at blood-heat, just as the muriate of ammonia and other sediments which often appear in the urine upon cooling, are held in solution at the natural heat of the body. On trying the effect of artificial heat it was found that the serum became considerably clearer, but it was still opaque.—*Proceedings of the Philosophical Society of Glasgow*, Vol. I. p. 231.

A specimen of the white matter separated by the action of common salt and the filter, but too minute in quantity to admit of a satisfactory analysis, was found to be quite insoluble in ether and alcohol, while it dissolved in caustic potash. On boiling it in a solution of sugar of lead, it gave traces of black sulphuret. The conclusion is, therefore, that it contained no fixed oil, and consisted most probably of a *protein compound* like white of egg or muscle.

A further opportunity was afforded of examining the chemical qualities of this serum in some specimens obtained for illustration.

A man about thirty years of age, after fasting eighteen hours, dined upon twenty-four oz. of a pudding, consisting of two parts wheaten flour and one part suet, seasoned with salt. Two oz. of blood taken before the meal yielded a perfectly limpid serum. Seven ounces were taken three hours after the meal and the same quantity six hours after it. The serum from the former was like syrup, but a little white; that from the latter was milk-white. The white matter in the latter was separated by means of salt and the filter, and appeared similar to the substance before examined. It contained no fixed oil. The other specimen of serum threw up its cream spontaneously. It left upon the filter only a trace of white matter, but a notable proportion of a fixed oil, which was easily demonstrated by merely drying the filtering paper and holding it between the eye and the light. It can scarcely be doubted that this oil was derived from the suet of the pudding, while the white proteinaceous substance most probably represented the gluten of the flour. Thus two of the three elements of which the food consisted were found in the blood; but the starch, the most abundant of all, was sought for in vain.

It was subsequently found, however, that all blood ferments with yeast; hence it is possible that the starch is converted into sugar and thus reaches the blood in solution.

Objections to the Muriatic-Acid Theory of Digestion.—It has already been stated that objections have been urged against the idea that muriatic acid exists in a free state in the stomach. The experiment upon which the theory is built is an ambiguous one, and requires some elucidation. The experiments made by Blondlot are completely opposed to the muriatic-acid theory, and, if they should prove to be accurate, will produce material changes in reference to our views of digestion. They are so important, that we shall give a short view of their nature.

Blondlot distilled in the water bath 3878 grains of the gastric juice as pure as possible. The juice was collected from dogs, a quarter of an hour after giving them beef to eat, and it was deprived of the mucus and other foreign matter by two filtrations. The distillation was performed with the greatest precautions in a tubulated glass retort, to which a receiver previously washed with distilled water was adapted. The heat was continued until $\frac{4}{5}$ of the fluid had passed into the receiver, which required about 24 hours. The product was colourless—clear and limpid like water: it had no decided taste, but it possessed a characteristic smell—it had no action on red or blue turnsol, however long it was kept in contact with it. The *residue* appeared at first slightly turbid; but after standing, during which it deposited a few flocks, which appeared to be coagulated mucus, it acquired perfect transparency. Its colour was reddish-brown—its smell was empyreumatic, its taste strongly salt and acid, and it reddened turnsol paper slightly, so that it was evident that the residue contained all the acid of the juice four times concentrated. This residue was distilled to dryness, which required several days. The product in every respect resembled the preceding, and had no action on test paper. The solid residue, 775 grains in weight in this case, soon began to attract moisture from the atmosphere, and to be converted into a soft matter of a blackish-brown colour; its odour was that of most extractive substances, its taste strongly salt and acid.

Blondlot repeated this important experiment several times with precisely the same results in each case. He considers that the distillation ought to be performed slowly, otherwise the distilled fluid may carry over some common salt or muriate of ammonia. To distill the quantity mentioned, he required 4 or 5 days. He concludes that neither acetic nor muriatic acid exists in a free state in the stomach. He found that on attempting to neutralise the fluid with chalk, there was no effervescence; while the liquor retained all its acidity even after allowing the chalk to remain some days in contact with it. He then suspected the acidity to be due to phosphoric acid. He found that when chalk is added to phosphoric acid, till all effervescence ceases, the solution is still acid, which it does not lose even by long boiling; and this, he says, is the only acid which so acts with chalk.

To determine this more accurately, he made the following experiments:—Having placed a quantity of gastric juice in a glass, he added a few drops of sulphuric acid. In two or three minutes, an abundant white precipitate fell, which when examined proved to be sulphate of lime. By *oxalic acid* a white precipitate fell, which when calcined on a plate of platinum left quicklime. Abundant precipitates were produced by *potash*, *soda*, and *ammonia*; by *lime water*, still more abundant precipitates. Each of these precipitates, when collected, was found to be neutral phosphate of lime.

A quantity having been dried and ignited, left a small portion of a grey cinder, not deliquescent, which was digested in water. The solution was not acid, did not precipitate on adding ammonia or nitrate of silver; the residue dissolved without effervescence in muriatic acid, forming chloride of calcium; proving that this ash consisted almost exclusively of neutral phosphate of lime, the excess of phosphoric acid having been decomposed by the charcoal of the organic matter and the other salts. From these facts he concludes, that the acidity of the gastric juice is due to *acid phosphate of lime*, or *biphosphate of lime*.

When the juice is evaporated and digested in strong alcohol, the solution deposits common salt and also plates of salmiac, mixed with a little phosphate of soda and ammonia, produced probably by the influence of heat upon the common salt, and a little acid phosphate of ammonia. The latter he supposes probably to exist in the juice, of which he gives the composition as follows:—

	Water,	99·
Salts.	Acid phosphate of lime,	1·
	Acid phosphate of ammonia,	
	Common salt,	
Organic.	Aromatic principle,	
	Mucus,	
	Peculiar matter,	

In this table there is no mention of vegetable matter, showing that his experiments had been made only with animal substances.

Gastric juice is neutralized by carbonates and bicarbonates of potash, soda, and ammonia, the neutral phosphate of lime being precipitated. The same effect is produced by the neutral and alkaline subphosphates, except in the absence of effervescence. Quick-lime neutralizes the acidity with precipitation of neutral phosphate and disengagement of ammonia. When the food has been converted into chyme by the gastric juice, it is pushed forward by the contractions of the stomach into the duodenum, the first portion of the small intestines, into which the pancreatic juice as well as the contents of the gall bladder are poured. Here, therefore, the chyme is mixed with the bile and the pancreatic juice. Its acidity now gradually disappears. By the contractions of the successive portions of the intestines, it is steadily propelled along. During this course it separates by degrees into chyle, which is absorbed by the lacteals; and into the innutritious and indigestible matter, which is carried onward along the intestinal canal.

The chyle is to be regarded as blood in an early stage of formation. As it is mixed with the blood just before its entrance into the lungs, and as it never can be recognized after the blood has emerged from that organ, it is probable that it undergoes some vital change here which completes its assimilation, but of the nature of this change we are ignorant.

In conclusion, it is important to bear in mind, that the whole process of digestion, although perfectly uninfluenced by any voluntary act of the mind, yet is materially affected by mental emotions and sensations, and that the secretion of gastric juice by the stomach appears to be very remarkably under such influence.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXIII.

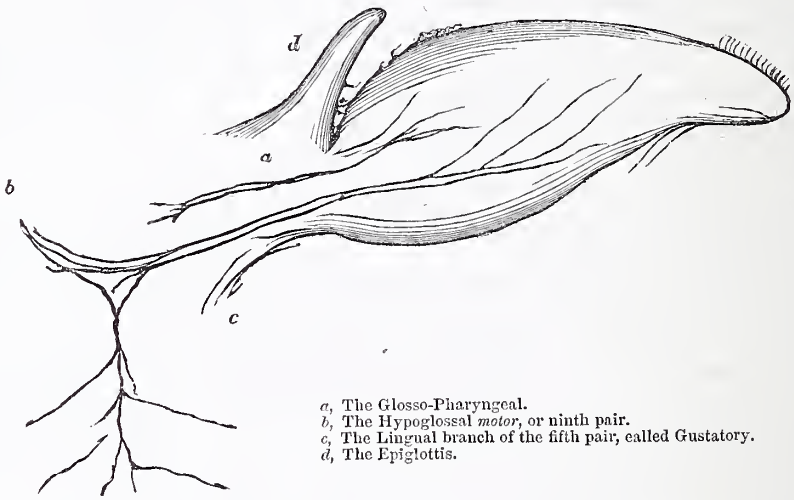
ON THE FACULTIES OF SENSATION AND PERCEPTION.—ORGAN OF TASTE.

THE sense of taste is described to be that which results from the contact of certain substances, termed sapid, upon the tongue, gums, and palate. It is, however, dependent on common sensation, along with that of smell produced by the odour arising from many bodies.

The uses of taste, besides its being a source of enjoyment, are to excite the flow of the saliva and mucus which are to prepare the food for the stomach, and to inform us of qualities in the objects which excite it, which bear a certain relation to their salubrity and digestibility. This latter use is better exemplified in animals than in the human species, although in man, during sickness, it is generally a very safe guide.

The structure of the tongue, the principal organ of taste, presents stronger analogies with that of the skin than any other organ. Its minute anatomy need not be dwelt on here. The accompanying figure will give the reader a sufficiently accurate idea of the larger muscles and nerves composing the bulk of the organ. By consulting the note containing the explanation of fig. 1, he will readily enough understand the general form of the organ, and its connections. The whole tongue is extremely mobile in every sense; and the strong and large muscles enumerated below connect it with the lower jaw and hyoid bones. These are also called, from this circumstance, lingual bones, from *lingua*, the tongue. These muscles enter deeply into its composition; but there are also numerous layers of muscles which may be called *intrinsic*, because they do not go to or come from any other part, but are limited solely to the tongue. By means of these the tongue may be elongated, and even be made to protrude from the mouth; again withdrawn and forced to strike against the teeth and palate; or sweep the inside of the mouth, or passed up between the cheek and jaws. The epiglottis, or covering of the air-passages, follows the movements of the tongue; hence the danger of keeping the tongue protruded from the mouth, and at the same time attempting to swallow food or drink, or indeed any body whatever. All the upper and a portion of the lower surface, together with the sides of the tongue, is invested in man, and of course in animals resembling him generally, with a reflexion of the common integuments of the body, or at least with a prolongation of what is called the mucous membrane. On the surface may be seen a number of projecting points, called papillæ, which, like all the rest of the surface, is covered with *epithelium* or scarf-skin. The fur covering the tongue in fevers and other disorders, is probably an altered and vitiated secretion of this epidermis, secreted of course by the subjacent vascular layers. When rubbed entirely off at any point, the papillæ are found to be most acutely sensible. Beneath this epithelium is the *pigmentum*, and the lingual rete-mucosum, as in other parts of the skin. The pigment is not visible in man, but is evident in the tongues of many animals: these parts are epidermic, and of course

Fig. 1.
Diagram of the Nerves supplying the Human Tongue.



a, The Glosso-Pharyngeal.
b, The Hypoglossal *motor*, or ninth pair.
c, The Lingual branch of the fifth pair, called Gustatory.
d, The Epiglottis.

extra-vascular and squamous. Beneath these epidermic parts is found the chorion or true skin, and into this a great number of muscular fibres are inserted on its deep surface; whilst on the other surface, immediately covered by the epidermic parts, numerous *nervous papillæ* project, almost forming a continuous layer, which, however, cannot be separated distinctly from the chorion. These papillæ are vascular and nervous, and probably form the true gustatory part. They are differently arranged, and seem even to have different forms in different animals; in man, they have been arranged as follows:—1st, The large or caliciform papillæ towards the base of the tongue; 2d, The conical; 3d, The tenticular; 4th, The filiform. These may all have different functions; but this is a point not well understood. The nerves of the tongue are three on each side, and they are of great size. The ninth pair of nerves supplies its muscles, and a large branch of the fifth pair, and a division of the glosso-pharyngeal, are also distributed chiefly to its surfaces. The glosso-pharyngeal nerve—we mean, of course, its lingual portion—is distributed chiefly to the surface at the base of the tongue; the fifth pair towards the apex; the ninth pair to the muscles throughout. An injury done the ninth pair, has been known to destroy the muscular power of the tongue, without affecting its sensibility or its gustatory powers.

The cavity of the mouth in which the tongue is placed, communicates at most times with another cavity placed immediately behind it, called the pharynx; but the orifice of communication may be, and is frequently closed by the descent of the soft palate, and elevation of the base of the tongue. The muscular action effecting this takes place generally involuntarily, or, as it may be termed, instinctively; and hence the occasional necessity for depressing the tongue with the handle of a spoon, or such other body, when we are desirous of examining into the state of the cavity beyond it. Large portions of the tongue have been removed without much interfering with speech or deglutition. A deep wound at the base of the tongue is always dangerous, and but too often fatal.

In the centre of the tongue is a palate or layer of a peculiar elastic substance, analogous to what we find in the back of the neck of sheep, oxen, and horses; and two large arteries supply the substance of the tongue with blood. Corresponding veins return the blood from these arteries.

The frenum, or bridle of the tongue, is a fold of membrane binding down a portion of the inferior surface of the tongue, but leaving the apex free. When too short in newborn children, it requires being divided by the surgeon. The operation ought to be performed with great caution; and, moreover, it is seldom requisite.

We have alluded above to the free though occasionally interrupted communication between the mouth and the cavity placed behind it—namely, the bag of the pharynx. By this aperture in man, air passes as readily to the windpipe and lungs as it does by the nostrils. It would seem, however, that in some animals, as in the horse, the passage of communication is not equally free, and is only fully opened when the food and drink are pressing from the one cavity to the other, it being generally understood that the horse cannot breathe by the mouth: he attempts it, however, when distressed, but probably without much real benefit. In like manner, it is almost certain that neither the elephant nor whales generally can ever, under any circumstances, breathe by the mouth.

The tongue, whose anatomy we have just described, is admitted by all to be the organ of taste. According to most physiologists, it is even perhaps still maintained to be the only part capable of perceiving the sapid qualities of bodies, this power being denied by them to any other part of the mouth. The phreno-mesmerist himself has not yet ventured to assert that an infusion of quassia may be distinguished from sugar and water by the extremities of our fingers or toes. The experiments of the ingenious and accurate Weber led to the conclusion, that neither in the palate, nor in any other part of the mouth, is there any perception of taste. It is possible, however, that, in this respect, different persons are differently constituted; and it would appear that some individuals do really possess a power of tasting with the soft palate or uvula, and even with the ceiling of the mouth or hard palate. Again, much disputation has been held in regard to the portion of the tongue itself which may be supposed the most gifted with the perceptive gustatory powers; nor is this an idle question, seeing that it has a reference to the distribution of the nerves of the tongue, whose general course has been already described. The hypoglossal, or great lingual nerves, are now universally admitted to be the nerves of motion of the tongue; but whilst the branch of the fifth pair is considered by some as the proper gustatory nerve, others claim this function for the glosso-pharyngeal (see the figure); and others think that both nerves may be required, or that both are essential for a right perception of sapid bodies. The reader is here reminded, that three distinct nerves proceed on either side into the tongue—namely, the ninth pair, or hypoglossal; a large branch of the fifth pair; and a division of the eighth pair, called the glosso-pharyngeus, from its supplying, in part at least, both the tongue and the bag of the pharynx, that cavity into which the food is received from the mouth, and which is in fact placed between the mouth and the gullet. The difficulty with regard to these nerves is this: if the branch of the fifth pair, which supplies the tongue, be a nerve of special sensation, it would require to be shown especially how this happens, seeing that the other branches of the same pair of nerves are merely nerves of common sensation. The same remark applies in some measure to the glosso-pharyngeal.

Comparative anatomy does not furnish data to solve these questions. The tongue of birds, it is said, receives no branches from the fifth pair; yet the swan and the parrot are said to taste acutely. Most birds, however, seem to be extremely deficient in taste, the duck especially; but it might not be correct to say, that even in them the sense is wholly wanting. A strong epithelial or epidermic layer, and even spires, protect the surface of the tongue in many animals; structures by no means adapted to fit it for a delicate organ of special sensation, or to improve its qualifications in this respect. But at the same time it is to be remembered that in many animals, as the chameleon, the ant-eater, the giraffe, and even, perhaps, the ox, the tongue serves as an instrument of prehension, as well as of taste.

Cruel and but too frequently unnecessary experiments on living animals have shown that, by cutting across in the living animal one pair of nerves supplying the tongue, the motions of the tongue cease; but this class of experimenters (for the honour of humanity, it is pleasing to think that it is not a numerous class) are by no means agreed as to the effects which follow a section in the living animal of the other nerves supplying the tongue. Paniaza, one of the most minute anatomists, able surgeons, and distinguished physiologists of modern times, attempted thus to solve the question in regard to the functions of that nerve we call the glosso-pharyngeal; but it may be said that he failed. Some excellent observers are still opposed to his views.

The loss of the power of taste is rare, but it sometimes happens. It is undoubtedly a great misfortune. We have known persons so affected terminate their career by suicide. The coincidence, however, may have been purely accidental.

Mechanical and galvanic stimulants applied to the tongue excite vague sensations, which no doubt, however, bear some analogy to sensations of taste. Again, many experiments have been made to determine what portions of the tongue are best endowed with gustatory properties; and it seems generally agreed, that the lower surface of the tongue, and the back part of the upper surface, are best endowed with such properties. Few persons can taste with the point of the tongue. The anterior half of the upper surface of the tongue is scarcely, if at all, equal to the perception of sapid bodies; and it has even been observed that certain substances give different sensations when applied to different

parts of the tongue. What is called the *after-smack,* seems to be of a compound nature, derived from various sources.

Taste is susceptible of education to a certain extent, as in the instance of wine and tea tasters. And there is even a sort of harmony in tastes, as well as in tones and colours. But different bodies must not be tasted too rapidly, else all power of discrimination ceases: and as regards the metaphysical history of the function, it may be said that the perceptions derived from it are much more objective, and less of a subjective nature than those of the higher organs of sight and hearing; or in other words, false sensations, sensations arising in the tongue and brain when no sapid body is present to excite them, are extremely rare when compared with the frequency of visual and auditory spectra. Their possible occurrence has even been doubted.

In the first part of this article on the sense and organ of taste, it has been shown how completely the tongue is a muscular organ, endowed with the utmost *mobility,* and also with common *sensibility.* It is therefore an instrument, and no doubt the chief instrument of speech; and with it the properties of bodies may to a certain extent be detected; for the determining of these, however, the fingers are by far the more appropriate instruments. The author of this article suggested, many years ago, to Sir Charles Bell, that the tongue of man was by no means so accurate a *tactile* organ as the fingers, although it might be so in some animals; and he instanced the fact that the pulse of the wrist could not in general be perceived by the tongue being applied over the artery, or at least only in an extremely obscure way, and that the number of pulsations could not be determined by the application of the tongue. By pressing, however, very strongly with the tongue against a very prominent artery, the pulsations of the heart may be counted and the thrill of blood in the vessel becomes evident. This does not, however, affect the main physiological proposition implied in the above remark, namely, that it is the presence of the skeleton in the finger which enables us to detect so readily with it the varieties in the number, force, and regularity of the pulsations of the heart as detected in the arteries; and that in the tongue of man it is the absence of any hard parts which unfits it in this respect as a tactile organ. The tongue of birds, therefore, may be an excellent tactile though an imperfect tasting organ. To resume, the conditions for the perception of taste in a sapid body seem to be, 1st, the presence of a nerve, with special endowments. 2d, The irritation of this nerve by the sapid matters. 3d, The solution of these matters in the secretions of the organ of taste. A calm investigation of all the facts shows that in regard to the special functions of particular nerves supplying the organ, a single well-observed, properly described case of disease in man is of infinitely more value than all the cruel and absolutely unnecessary and therefore brutal experiments performed on living animals specifically distinct from man. "The pressure of a tumour or swelling on the divisions of the fifth pair of nerves, caused loss of taste in the corresponding half of the tongue." This does not, it is true, prove that the nerve implicated is the sole and only nerve of taste; but it proves that if the glosso-pharyngeal be the nerve, it cannot act an independent part, but requires the aid of the fifth.*

The varieties in the sensation of taste are less understood than in the case of sounds and colours. The theoretical terms of taste, then, are unknown, a statement which we hope will please the taste of those who are constantly declaiming against *theory,* giving a preference to what they are pleased to call *facts.* And it is consoling at the same time to know that there exists nothing in the facts more absolutely at variance with the usually received physiology of the nervous system.

We had almost forgot to add that the tongue is liable to many diseases, some of which require the bold and firm interference of the surgeon. Bleeding caused by an injury to the tongue is occasionally restrained with difficulty, requiring at times the application of the actual cautery or red-hot iron. To malformation of the organ some surgeons have been disposed to ascribe the impediment of speech called stammering; and some very cruel and extremely improper operations have been performed by Dieffenbach and others, with a view to a removal of the complaint. Such operations are not warrantable; and the operators, whoever they are, forget a great principle, which ought to regulate all surgeons, —namely, that an operation is not to be performed merely because it can be done, but rather because it is advisable and prudent to perform it under existing circumstances.

* If it be true that the tongue may lose its *common sensibility,* and yet preserve its power of taste, this would show the uses of the fifth pair to be more complex than are generally supposed.

II.—Of the Organ of Smell.

The term nose, as it is used in ordinary language, does not include all the structures required for the apparatus of smell. The more important, and indeed the more essential parts, as in the case of the ear, are placed more deeply in a cavity formed within the bones of the face, above the organ of taste and at the entrance of the air passages. It is a double organ, or composed of two cavities quite distinct from each other.

The *nose,* or the external visible part, varies infinitely as to its form, particularly amongst the inhabitants of England and the Lowlands of Scotland. This so great variety arises no doubt from the commingling of so many races of men in these countries. It does not seem to me, however, that we meet with the same variety in the form of the nose amongst the purer races. In the negro, for example, or the Jew, or even the Irish Celt, there does not exist that extraordinary diversity of form in the shape of the nose which is met with among the English and Lowland Scotch. There is then a certain form of nose peculiar to each race, which admits only of a limited range as to its varieties. In the Jew I have observed but three varieties as to the form of the nose, and these are but slight modifications of what may be called the primitive form of the race. The finest form of the organ occurs in certain young persons of the Jewish race; and the same form precisely is to be seen in the head of the young Memnon, a granite bust of extraordinary beauty brought from Egypt and now in the British Museum. This was probably the form of nose common to most ancient Egyptians. On the other hand, the ancient Greeks (I mean, of the classic age) were beyond all doubt a mixed race, composed of Phœnician, Egyptian, Armenian, Saxon, and Celtic blood. Hence the infinite variety in their physiognomy. What is usually termed "the Greek nose" and Grecian profile, does not seem to be so common in Greece as some have supposed. Finally, this profile and form of nose is sufficiently common amongst the Saxon race, from whom, probably, it was derived. The origin of the Roman nose is not well understood, but evidently it has not been derived from any *Celtic race.*

In the nose, anatomists describe the summit or root, the *dorsum* or ridge, the *lobe,* and the base. In the base are the nostrils, bounded externally by the alæ or wings.

Moreover, the nose is composed of a skeleton or framework and of certain muscles; internally, it is lined with a mucous membrane; blood vessels, nerves, and lymphatics are found here as elsewhere; the common integuments invest the outer surface. This portion of skin has its peculiar sympathies.

Two bones, whose shape will be best understood by looking at figure 2, support the part we now speak of; their function is best judged of by observing what happens when by accident or disease they have been lost. The cartilages which assist in forming the nose, are the two *lateral* cartilages, the two outer cartilages; and to these may be added the great cartilage of the septum or middle division of the nostrils. Thus modern anatomists describe five cartilages in the nose. Santorini, an Italian anatomist, on the other hand, with the minuteness peculiar to the Italian character, described *eleven* cartilages, of which five may be said to be fully developed,

and six have been left by nature in a rudimentary state. Santorini, no doubt, was correct; and the view he took of the matter was not only the most philosophic, but in point of fact the only true view. These small nodules of cartilages, which in men are so imperfect, represent more fully developed cartilages in other animals. It is not in man that we are to look for the fully-developed apparatus of the nostrils.

A fibrous membrane connects all these cartilages to each other and to the adjoining bones. In fig. 2, *a a* show the form of the lateral cartilages; *b b* mark the cartilages of the wings, or alæ of the nose; and *e e*, the smaller rudimentary cartilages described by Santorini. The cartilage of the septum will be best understood by inspecting fig. 3. Aided by a bony plate descending from a bone termed ethmoid, this large and

Fig. 2.

Bones of the nose.

Lateral cartilages.

Cartilages of the wings.

Cartilages of Santorini.

Fig. 3.

a, The bony plate of the ethmoid.

b, The middle cartilage of the nose.

c, The vomer bone.

d, The hard palate.

important cartilage, the free margin of which may be seen between the nostrils, and whose loss even partially is so much felt by those to whom this misfortune has happened, divides the nostrils from each other; it is in fact the septum or partition wall.

The muscles acting on these cartilages have not yet been very accurately or minutely described; nor perhaps the nerves, which of course are distributed to these muscles. A partial view of them will be found in a preceding number. The fact which may perhaps most interest the reader is the obvious connection these muscles have with the respiratory or breathing system. The first act probably of the respiratory movement is to expand the nostrils; and the actual condition of the lungs may occasionally be judged of by the state of the nostrils and by the action of their muscles. The cartilages just described seem naturally to close the nostrils even in man at all times when not acted on by their muscles. In this respect, however, they are probably more perfect in the seal than in man; in the rorguel or great northern whale they are the most perfect. In this animal, cartilages which no doubt correspond by analogy with the lateral cartilages in man, project deeply into the nostrils on either side. Each is nearly as large as a bolster. By their extraordinary size and elasticity they plug up the nostrils, completely protecting them from any eruption of the waters of the ocean when the rorguel seeks its lowest depths; but when on the surface and at the breathing moment, large muscles, fixed by one extremity into the centre of these cartilages, and by the other to the bones of the face, acting simultaneously with the midriff and other breathing muscles, suddenly withdraw them more or less completely from the nostrils, thus clearing a wide passage for the descent of air into the lungs. So soon as this action ceases the cartilages return by their own elasticity into the nostrils. There is no mechanism connected with animal structures more wonderful than the one just described; and it is singularly wonderful and yet mysterious to observe how nature has employed, in this great respiratory act, similar materials throughout the whole range of the mammalia. The mechanism by which the nostrils are expanded in man is precisely similar to that in the rorguel; and the structures which to the mere matter of fact observer appear so different, are yet essentially the same and strictly analogous. Let us return, however, to man. The human structure is incomparably the most interesting to be known of all animals, although it may be readily conceded that a full knowledge of the uses of man's organs cannot be rightly attained without an occasional appeal to comparative anatomy.

The skin of the upper part of the nose differs evidently from that of the lobe and lower parts; this latter is extremely firm, and crepitates when cut; the sebaceous follicles are remarkably developed.

The interior of the nostrils is usually shown by two sections, given in figures 4 and 5; these figures expose the course of the lining membrane of the nose, usually called Pituitary or Schriedenium. Fig. 4 represents the outer

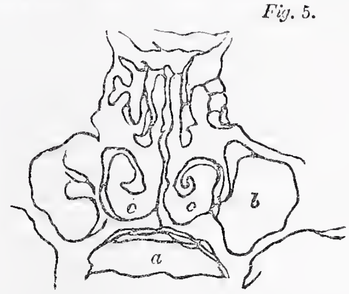
Fig. 4.

b, the middle turbinated bones, cut partly away.

a, the lower turbinated bones.

wall of the right nostril. The vascular membrane covers the whole of these surfaces. Where first seen at the edge of the nostrils, it is intimately united to, and may be considered continuous with, the skin.. Inwardly, it is prolonged to the middle ear and downwards towards the gullet and windpipe; it is extended, moreover, although modified into various bony cavities existing in the bones of the face and cranium, whose uses are far from being well understood. The orifices of some of these may be seen in the figure; the remarkable rolled-up structures are the lower and middle turbinated bones; these are also covered with the pituitary membrane, and by being so rolled up are presumed to offer a more extensive surface for sensation than would have been otherwise obtained in so confined a space. Certain it is that the sense of smell is always very strongly developed when these turbinated bones are found large and much rolled on themselves. It is upon this surface that the nasal tube opens, conveying the tears from the surface of the eyes into the nostrils. Fig. 5 presents an interesting view of both nostrils

Fig. 5.



a, palate.
b, sinuses or cavities in the cheek bones.
c, *c*, lower turbinated bones, cut across.

cut perpendicularly down about the middle; it may be readily enough understood by simply looking at the middle partition separating one nostril from the other.

The pituitary membrane is very vascular and is apt to bleed excessively from constitutional and other causes; the arteries are very numerous, and so likewise are the veins. Hence the great advantages to be derived occasionally by applying a leech or two to this membrane in deep inflammations of the nose; the plugging of the nostrils on the other

hand, to stop bleeding, is often a troublesome operation. Excrescences or polypi of various kinds grow from this membrane, and so, more or less completely interrupting the nasal passages, affect the breathing; these should be removed by a skilful and careful surgeon. Lastly, two kinds of nerves at least are distributed to this membrane; first, the *olfactory* or first pair of cerebral nerves; secondly, a branch from the fifth pair of cerebral nerves. Nearly all agree that the first are properly speaking the true *olfactory* nerves. The branch from the fifth is supposed to bestow on the membrane the common sensibility which with other parts of the body it requires. There are difficulties, however, in adopting this simple view of the physiology of these nerves, which we shall state in the next section. We shall now briefly give the history of the physiology of this sense.

"The sense of smell takes cognizance of the particles of odorous bodies which are held suspended or dissolved in the air." This is the definition of most physiologists; but the term "or in water" must be added, if we propose including fishes amongst those animals which have the power of smell. It is generally understood and admitted that the odorous particles are perceived by the *olfactory* or first pair of nerves, although, as we shall afterwards find, a branch of another pair of nerves, the fifth, is also required to fit the organ for the exercise of its function. The *olfactory* nerve is presumed to be distributed extensively on the mucous membrane investing the deeper cavities of the nostrils.

There can be no doubt that all analogy is in favour of the idea that the olfactory nerves are truly what their name implies them to be; yet cases occur in which an injury done to that small branch of the fifth distributed to the mucous membrane and lobe of the nose has completely destroyed the power of smell. Such pathological cases present great difficulties, and are in a great measure as yet inexplicable by any physiological theory, like many of the beautiful views of Sir Charles Bell and Mr Walker, for example, in regard to the nervous system.

It has not been proved satisfactorily that fishes smell, and yet they have very large olfactory nerves. Birds also have but imperfect olfactory organs; in them the first pair of nerves is small. The vulture, which was long thought to discover his prey by the sense of smell, has been proved to possess this power in an extremely limited degree, and so of other birds. On the other hand, it is probable that some hot-blooded animals of the order Cetacea, as the well-known porpoise, have olfactory nerves so small, that many anatomists doubt their existence; and from this it is fair to presume, that such animals smell very imperfectly, if at all. This remark, however, does not apply to all Cetacea, the rorguel or piked whale having an olfactory nerve as large, proportionally, as man himself. But it is in the horse, ox, deer, &c. that the sense of smell appears to be most highly developed; by this sense, the horse declines not unfrequently to taste water which to man's senses would appear to be pure; by it also he would seem to discover in the open field the approach of enemies or friends. On the unenclosed fields of the Cape of Good Hope, the farmers' horses are turned out to graze and in some measure to shift for themselves, being altogether without protection from man. It may be owing to this that they exhibit instincts and a sagacity unexpected and occasionally remarkable. They collect in circular groups on the approach of danger, the mares and younger horses occupying the centre, whilst a stallion or gelding leaves the party and gallops towards the suspected object. As he approaches the object of his fear or rather suspicion, (for if a stallion he seldom shows fear,) it is curious to observe how he, by a long circuit, places the person or animal between him and the point whence the wind blows, however slight the current of air may be; or, in other words, how he almost uniformly prefers exercising the organ of smell to that of sight. Another circumstance worthy of notice in regard to this organ is that the antelope, zebra, quagge, and wildebeest or gnoo, frequenting in countless numbers the vast grassy plains and mountains of Southern Africa, do uniformly, when pursued by the huntsman, gallop up towards the quarter from whence the wind blows; and African farmers have often pointed out to me the curious fact, that oxen, when turned out to graze on the unenclosed field or desert, do very generally, if not uniformly, graze towards the same quarter, as if desirous of ascertaining whilst feeding, by means of the organ of smell, the approach of any dangerous or suspected object. In the pursuit of the young quagge, zebra, or antelope, it is sufficient merely to press the hand several times over its nostrils when it is overtaken, as on being let loose it will follow the huntsman into bondage, even although its parents may be seen free at no great distance and the liberty of flight freely permitted it.

The power of smell in the dog and pig need not to be adverted to, as being so well known. That of the elephant is probably extremely acute.

The power of smell and even its character vary much in different persons. Females generally prefer perfumes and sweet smells; flowers are generally agreeable to them on this account. The sense of smell is extremely acute in some persons, and is not impaired by a residence amongst unpleasant odours.

PRINCIPLES OF ALGEBRA.

CHAPTER VII.

Of Simple Equations containing more than one Unknown Quantity.

66. Suppose that there exist *simultaneously* two such equations as

$$x + y = 15 \qquad\qquad x - y = 7$$

in which we have two unknown quantities, x and y, and two independent conditions expressed regarding them. It is here obvious that the single condition of either of these equations is not sufficient to fix the value of the quantities; it connects them, nevertheless, in such a way, that if one can be found, the other can be found also. Taken separately, the equations are therefore *indeterminate*, or admit of an indefinite number of solutions: for the first will manifestly be satisfied by any pair of numbers whose sum is 15, and the second by any pair of numbers whose difference is 7. The following are instances :—

Solutions of the first.		Solutions of the second.	
$x = 12$	$y = 3$	$x = 12$	$y = 5$
$x = 11\frac{1}{2}$	$y = 3\frac{1}{2}$	$x = 11\frac{1}{2}$	$y = 4\frac{1}{2}$
$x = 11$	$y = 4$	$x = 11$	$y = 4$
$x = 10\frac{1}{4}$	$y = 4\frac{3}{4}$	$x = 10\frac{3}{4}$	$y = 3\frac{3}{4}$

and so on for as many pairs of numbers as we please. But the solution required here consists in finding a set of values for x and y, which shall simultaneously satisfy both equations. Such a solution is contained among the preceding instances, where we find a set of values, $x = 11$ and $y = 4$, which satisfies both equations at once.

A group of equations of this sort, in which we have the same number of equations and unknown quantities, is called a *system of simultaneous equations;* and the first part of the process of solution consists in *eliminating* one of the unknown quantities; that is, by some combination of the two equations to derive a new equation from which one of the unknown quantities shall be excluded. The following are the methods usually employed with equations involving two unknown quantities :—

67. First Method.—*By substitution.*—Find an expression for one of the unknown quantities from one of the equations, and substitute it for that unknown quantity in the other equation. The result will be an equation containing only one unknown quantity, and may therefore be solved by the methods already given.

Let the proposed equations be of the general forms *

$$a x + b y = c \qquad\qquad a' x + b' y = c'$$

* To avoid using many different letters, it is common to employ the same letter with one or more accents, to signify different numbers. Thus: The symbol a' differs as effectually from a as a does from b. As to the meaning of the numbers for which they stand, a' may be read "a" *accented;* but it is more commonly read "a" *dash,* though not so correctly. The same applies to b', c', or any other accented symbol.

From the first equation we get $x = \dfrac{c - b\,y}{a}$

And this value substituted for x in the second, gives

$$a'\left(\frac{c - b\,y}{a}\right) + b'\,y = c', \quad \text{or} \quad \frac{a'\,c - a'\,b\,y}{a} + b'y = c'$$

$$\text{whence } y = \frac{a\,c' - a'\,c}{a\,b' - a'\,b}.$$

To obtain x, find y from the first equation, and repeating the process, find

$$y = \frac{c - a\,x}{b} \qquad a'\,x + \frac{b'\,c - a\,b'\,x}{b} = c' \qquad x = \frac{b\,c' - b'\,c}{a'\,b - a\,b'}$$

Or substitute the value of y first obtained in the previous expression for x; thus:

$$x = \frac{c - b\,y}{a} \qquad b\,y = \frac{a\,b\,c' - a'\,b\,c}{a'\,b - a'\,b}$$

$$c - b\,y = \frac{a\,b\,c - a'\,b\,c - (ab\,c' - a'\,b\,c)}{a\,b' - a'\,b} = \frac{a\,b'\,c - a\,b\,c'}{a\,b' - a'\,b} = \frac{a(\,b'c - bc')}{ab' - a'b}$$

$$\therefore \frac{c - b\,y}{a}, \text{ or its equivalent } x = \frac{b'\,c - b\,c'}{a\,b' - a'\,b}$$

Numerical Example.—Find the values of x and y from the equations

$$\tfrac{1}{2}\,x + \tfrac{1}{4}\,y = 6\tfrac{1}{2} \qquad \tfrac{3}{8}\,y - \tfrac{1}{10}\,x = \tfrac{33}{40}.$$

In this and all similar instances, we begin by clearing the equations of fractions: the process gives

$$2\,x + y = 26 \qquad 15\,y - 4\,x = 33.$$

Find the value of the unknown quantity least involved, which is y in the first equation: we get

$$y = 26 - 2\,x.$$

And this value substituted for y in the second equation, gives $15\,(26 - 2\,x) - 4\,x = 33$; whence $x = 10\tfrac{1}{2}$.

Substituting this value of x in the expression for y, gives $y = 5$.

68. Second Method.—*By Equating.*—Find a value of one of the unknown quantities from each of the equations, and equate these values—that is, make them the members of a new equation. The resulting equation will contain only one unknown quantity.

$$\text{Let} \quad a\,x + b\,y = c \qquad a'\,x + b'\,y = c'$$

$$\text{From the first equation,} \quad y = \frac{c - a\,x}{b} \qquad x = \frac{c - b\,y}{a}$$

$$\text{From the second equation,} \quad y = \frac{c' - a'x}{b'} \qquad x = \frac{c' - b'y}{a'}$$

Equate the values of y with each other, and the values of x with each other,

$$\text{We get} \quad \frac{c - a\,x}{b} = \frac{c' - a'\,x}{b'} \quad \text{whence} \quad x = \frac{b'\,c - b\,c'}{a\,b' - a'b}$$

$$\text{And} \quad \frac{c - b\,y}{a} = \frac{c' - b'\,y}{a'} \quad \text{whence} \quad y = \frac{a\,c' - a'\,c}{a\,b' - a'b}$$

Numerical Example.—Find the values of x and y from the equations

$$x + \frac{3\,y - 2\,x}{7} = 12\tfrac{3}{7} \qquad \frac{7\,x - 9\,y}{3} = 1.$$

These equations, reduced to their simplest forms, are—

$$5\,x + 3\,y = 87 \qquad 7\,x - 9\,y = 3.$$

$$\text{From the first we get} \quad y = \frac{7 - 5\,x}{3} \qquad x = \frac{87 - 3\,y}{5}$$

$$\text{From the second we get} \quad y = \frac{7\,y - 3}{9} \qquad x = \frac{3 + 9\,y}{7}$$

$$\therefore \frac{87 - 5\,x}{3} = \frac{7\,y - 3}{9} \text{ whence } x = 12$$

$$\therefore \frac{87 - 3\,y}{5} = \frac{3 - 9\,y}{7}, \text{ whence } y = 9.$$

69. Third Method.—*By Equalising the Coefficients.*—Reduce and multiply (or divide, if more convenient) both equations in such a way that the terms which contain the same unknown quantity in each equation, may have the same coefficient; then *add* the two resulting equations together, if the signs of the terms whose coefficients are thus equalised be *unlike;* but *subtract* the one from the other, if the signs be *like;* and one of the unknown quantities will thereby be eliminated. Having found the value of one of the unknown quantities from this new equation, the value of the other may be determined either by repeating the process upon the given equations, or by substituting in either of them the value of the unknown quantity already determined.

Generally, the shortest method of equalising the coefficients is this: *Multiply each equation by the coefficient which the quantity to be eliminated has in the other equation.*

$$\text{Let} \quad a\,x + b\,y = c \qquad a'\,x + b'\,y = c$$

To eliminate x *and find* y

Multiply the first equation by a', and the second by a, we then get

$$a\,a'\,x + a'\,b\,y = a'\,c \qquad a\,a'\,x + a\,b'\,y = a\,c'.$$

Subtract either of these products from the other: the first from the second gives

$$(a\,b' - a'\,b)\;y = a\,c' - a'\,c \qquad \therefore y = \frac{a\,c' - a'c}{a\,b' - a'\,b}$$

To eliminate y *and find* x

Multiply the first equation by b', and the second by b, we get

$$a\,b'\,x + b\,b'\,y = b'c \qquad a'\,b\,x + b\,b'\,y = b\,c'$$

Subtract one of these products from the other: the second from the first gives

$$(a\,b' - a'\,b)\,x = b'\,c - b\,c' \qquad \therefore x = \frac{b'\,c - b\,c}{a\,b' - a'b}$$

Numerical Example.—Find x and y from the equations.

$$3\,x - \frac{x - y}{2\frac{1}{2}} = 2\,y + 11 \qquad 6\,y - \frac{2\,y - x}{4} = 3\,x + y + 1$$

These equations, reduced to their simplest forms, are

$$13\,x - 8\,y = 55 \qquad 18\,y - 11\,x = 4$$

To eliminate x: multiply the first equation by 11, and the second by 13, and get

$$143\,x - 88\,y = 605 \qquad 234\,y - 143\,x = 52$$

The signs of the terms containing x are unlike, therefore add these results, and get

$$146\,y = 657 \qquad \text{whence} \qquad y = 4\tfrac{1}{2}$$

This value of y substituted in the equation $13\,x - 8\,y = 55$, gives

$$13\,x - 36 = 55 \qquad \text{whence} \qquad x = 7$$

70. Since, then, two equations are *necessary* and *sufficient* for the determination of two unknown quantities, it follows that when an algebraical problem requires for its solution the determination of two unknown quantities, it must give rise to an *equal number of independent and consistent equations.*

1° *The equations must be independent:* that is, each must contain a separate condition not fulfilled by the other, nor derivable from it. For instance, the equations

$$x + y = 15 \qquad x - y = 7$$

are independent of one another, as they involve separate conditions regarding x and y. But the equations

$$2\,x + 2\,y = 30 \qquad \tfrac{1}{2}x + \tfrac{1}{2}y = 7\tfrac{1}{2}$$

are both deducible from $x + y = 15$, and do not involve any new condition. They are therefore *dependent*, and admit of all the solutions of the original equation. To show to what our rules lead in cases of this sort,

$$\text{Let} \left.\begin{aligned} a\,x + b\,y &= c \\ a'\,x + b'\,y &= c' \end{aligned}\right\} \quad \text{give} \quad x = \frac{b'\,c - b\,c'}{a\,b' - a\,b'}\,y = \frac{a\,c - a\,c}{a\,b' - a\,b}$$

Supposing that $a' = m\,a$, $b' = m\,b$, $c' = m\,c$: then

$$a' x + b' y = c' \text{ becomes } m\,a\,x + m\,b\,y = m\,c$$

and striking out the common factor m, this becomes $a\,x + b\,y = c$, which is the same as the first equation. Substitute now the values $m\,a$, $m\,b$, $m\,c$, of a', b' c', in the expressions for x and y: we get

$$x = \frac{m\,b\,c - b\,m\,c}{a\,m\,b - m\,a\,b} = \frac{0}{0} \qquad y = \frac{a\,m\,c - m\,a\,c}{a\,m\,b - m\,a\,b} = \frac{0}{0}$$

which is the same anomaly as that noticed in Art. 65, with the same interpretation.

2° *The equations must be consistent:* that is, they must not contradict each other, such as the following :—

$$x + y = 10, \qquad x + y = 12,$$

which are evidently incongruous, and cannot *both* be satisfied with *one* set of values of x and y. The first subtracted from the second, gives

$$(x + y) - (x + y) = 12 - 10; \qquad \text{that is, } 0 = 2,$$

an absurdity of the same kind as $a\,x = a\,x + 1$, the only answer to which is infinity (Art. 64.) To show that every pair of simultaneous equations exhibit the same anomalous result when their first members are *reducible* to identity, and their second members are not, let us again recur to the general equations,

$$\left.\begin{array}{l} a\,x + b\,y = c \\ a'x + b'y = c' \end{array}\right\} \text{ which gives } x = \frac{b'\,c - b\,c'}{a\,b' - a'\,b}, y = \frac{a\,c' - a'\,c}{a\,b' - a'\,b}.$$

By putting $a' = m\,a$, $b' = m\,b$, $c' = n\,c$, the equation becomes

$$m\,a\,x + m\,b\,y = n\,c \qquad \text{whence} \qquad a\,x + b\,y = c\,\frac{n}{m}$$

and these values of a', b', c', being substituted in the value of x and y, we get, after reduction,

$$x = \frac{c\,(m - n)}{0} = \infty \qquad y = \frac{c\,(n - m)}{0} = \infty\,.$$

3° *The number of equations must not exceed the number of magnitudes to be determined.*—If, for instance, *three* equations be proposed to determine the values of *two* unknown quantities, one of the equations will be dependent on, or deducible from, the others, and therefore unnecessary; or it will be incompatible with *both* the others, though not inconsistent with either of them taken *singly*. Take, for example, the equations

$$x + y = 11 \qquad 3\,x - 2\,y = 8 \qquad 7\,y - x = 13$$

and solve them pair and pair together: we find that

The 1st and 2d are true if $x = 6$ and $y = 5$.

The 1st and 3d are true if $x = 8$ and $y = 3$.

The 2d and 3d are true if $x = 4\frac{6}{19}$ and $y = 2\frac{9}{19}$.

Tho following are examples of the manner in which problems requiring the determination of two unknown magnitudes are translated into algebraical language :—

Problem I.—Nine men and seven women receive together £3 11*s.* 2*d.* for their wages, and it is found that seven men receive £0 19*s.* 8*d.* more than five women: required the wages of each person.

Let x and y represent the wages of each man and woman respectively in pence; then, by the question, we have

$$\left.\begin{array}{l} 9x + 7y = £3\ 11s.\ 2d. = 854d. \\ 7x - 5y = £0\ 19s.\ 8d. = 236d. \end{array}\right\} \text{whence} \left\{\begin{array}{l} x = 63d. = 5s.\ 3d. \\ y = 41d. = 3s.\ 5d. \end{array}\right.$$

Problem II.—A farmer mixed barley at 2*s.* 4*d.* a bushel, with rye at 3*s.* a bushel, and wheat at 4*s.* a bushel, and found that 100 bushels of the mixture was worth 3*s.* 4*d.* per bushel. Had he used double the quantity of rye and 10 bushels more of wheat, the whole would have been worth exactly the same per bushel. Required the quantity of each kind of grain in the mixture?

Let x = the number of bushels of barley, and y = the rye;
Then $100 - (x + y) = 100 - x - y$ = the bushels of wheat.
Now, $28\,x + 36\,y + 48\,(100 - x - y)$ is the price of the whole in pence; but 100×40 is also the price of the whole at 3*s.* 4*d.* per bushel.

$$\therefore 28x + 36y + 48(100 - x - y) = 4000 \qquad (1)$$

Again, on the second hypothesis, we get similarly

$$28x + 72y + 48(110 - x - y) = 40(110 + y) \quad (2)$$

$$\left.\begin{array}{l} \text{From equation (1) we get } 5x + 3y = 200 \\ \text{From equation (2) we get } 5x + 4y = 220 \end{array}\right\} \text{whence} \left\{\begin{array}{l} x = 28 \\ y = 20 \end{array}\right.$$

Also, $100 - x - y = 100 - 28 - 20 = 52$; so that the mixture consists of 28 bushels of barley, 20 of rye, and 52 of wheat.

Problem III.—There is a number consists of two digits, to which, if the number formed by changing the places of the digits be added, the sum is 121; and if the one number be subtracted from the other, the remainder is 9. Required the number.

Let x and y represent the digits, then will

$10y + x$ = the number sought.
And $10x + y$ = the number formed by changing the places of the digits.

$\therefore 11x + 11y$ = the sum of the Nos., and $9x - 9y$ = their difference.

$$\left.\begin{array}{l} \text{But } 11x + 11y = 121, \text{ or } x + y = 11 \\ \quad 9x - 9y = 9, \text{ or } x - y = 1 \end{array}\right\} \quad \therefore \quad \left\{\begin{array}{l} x = 6 \\ y = 5 \end{array}\right.$$

Consequently, 56 or 65 is the number required.

71. The three methods of elimination exemplified may be extended to all simple equations, whatever be the number of unknown quantities involved. Instead of repeating the rules, we will give an instance of the application of each.

$$\begin{array}{llr} \text{Let } & 5x + 3y + z = 20 & (1) \\ & 2x - 7y + 3z = 18 & (2) \\ & 17x + 8y - 5z = 7 & (3) \end{array}$$

By Substitution.—*First Method.*

$$\text{From equation (1)} \qquad z = 20 - 5x - 3y \qquad (A)$$

Substitute this value of z in equations (2) and (3), and reduce;

$$\left.\begin{array}{ll} \text{Equation (2) becomes} & 13x + 16y = 42 \\ \text{Equation (3) becomes} & 42x + 23y = 107 \end{array}\right\} \text{whence} \left\{\begin{array}{l} x = 2 \\ y = 1 \end{array}\right.$$

and substituting these values for x and y in (A), we get $z = 7$

By Equating.—*Second Method.*

$$\begin{array}{llr} \text{From equation (1)} & z = 20 - 5x - 3y & (A) \\ \text{From equation (2)} & z = \dfrac{18 - 2x + 7y}{3} & (B) \\ \text{From equation (3)} & z = \dfrac{17x + 8y - 7}{5} & (C) \end{array}$$

Equating the first of these values of z with the second and third, we get

$$\left.\begin{array}{l} \text{(A) with (B) } 20 - 5x - 3y = \dfrac{18 - 2x + 7y}{3} \\ \text{(A) with (C) } 20 - 5x - 3y = \dfrac{17 + 8y - 7}{5} \end{array}\right\} \text{whence} \left\{\begin{array}{l} x = 2 \\ y = 1 \end{array}\right.$$

And substituting these values in any of the expressions for z, gives $z = 7$.

By Equalising the Coefficients.—*Third Method.*

Multiply both sides of (1) by 3, and z will have the same coefficient as in (2).

$$\begin{array}{llr} \text{Equation (1)} \times 3 & 15x + 9y + 3z = 60 & \\ \text{Equation (2)} & 2x - 7y + 3z = 18 & \\ \text{Subtract} & 13x - 16y \quad = 42 & \ldots (A) \end{array}$$

Multiply (2) by 5, and (3) by 3, and in the results z will have the same coefficient.

$$\begin{array}{llr} \text{Equation (2)} \times 5 & 10x - 35y + 15z = 90 & \\ \text{Equation (3)} \times 3 & 51x + 24y - 15z = 21 & \\ \text{Add} & 61x - 11y \quad = 111 & \ldots (B) \end{array}$$

The equations (A) and (B) being solved together, give $x = 2$, and $y = 1$; and these values substituted in any of the equations containing x and y, we get $z = 7$, as before.

Any like questions, involving the same or a greater number of unknown quantities, may be resolved by either of these methods.

LECTURES ON ARCHITECTURE.*

DELIVERED AT THE ROYAL ACADEMY, BY PROFESSOR COCKERELL.

LECTURE I.

It is an axiom with the civilized nations of the Continent, that the Fine Arts are eminently calculated to increase human happiness and exalt human character, and greatly contribute to the reputation as well as the real interest of a country—especially of a manufacturing country.

But the austere government of England makes the Fine Arts no part of its glory, its policy, or of its expense. And were it not for the sympathy and patronage of the public, even this limited Institution could not exist; nor would the country escape the reproach of the Celestials of "outer barbarism." The Fine Arts have, indeed, the countenance of the supreme head, and of "the powers that be"—the Ministers of the day, who cannot, as gentlemen, renounce the attribute of taste; but they have uniformly shown by their public conduct that they do not consider its support amongst the people a political duty.

It is now more than a hundred years since Thomson, the best informed upon the Arts of all our poets, indignantly remonstrated on our national inferiority and neglect of this branch of intellectual culture, and complained with grief in his Ode to Liberty—

> That finer arts (save what the Muse has sung,
> In daring flight above all modern wing,)
> Neglected droop their head.

Foreigners have attributed this disregard of the rulers of an ingenious and a great people to various causes—to physical insensibility, to the sordid nature of our commercial habits, or the adverse propensity of the Protestant religion,—to which objections the history of the ancient dynasties of this country (never inferior in the fine arts), the abundant enthusiasm of individual artists of our own times, and the public sympathy, are direct contradictions. Finally, they have fixed the reproach on the government, by pointing at the Schools of Design established by parliament; for they say, truly, that so soon as the inferiority of our design in manufactures drove us from the foreign markets, we took the alarm, and immediately formed schools of design, *à l'instar* of those on the continent; not from a generous love of art, but confessedly, from the well-grounded fear of loss in trade. The members of this Academy hailed the measure with joy, as the harbinger of a better sense of what is due to our intellectual position in Europe, and they have willingly given their gratuitous attention to its conduct. But the instruction of youth must be accompanied with the higher prospect of employment and honour in national works; and we are happy in the reflection that the decoration of the parliamentary palace at Westminster, and the interest taken by an illustrious personage in that great object, hold out to us the hopes of equality at least in these noble studies with the improving countries of the continent, and the opening of a new career for genius and industry.

But an erroneous and mischievous scepticism as to the utility of Academies of fine art altogether, has long been fashionable, which has not, however, been applied to others, for no one has ever yet despaired because a Newton or a Locke are not annually produced from Cambridge and Oxford; but of these it has been plausibly said, that no Michael Angelos, Raphaels, or Palladios have been produced by them since their foundation in the 17th century; it is forgotten, however, that the patronage and immense employment which elicited the talents of those masters, have also been wanting; and that without the field for their development, and all the expensive machinery by which they can be brought to bear, Academies can do little more than preserve and transmit the rudiments of art.

Fleets and armies are necessary for war, and without these the greatest captain of his day might have been nothing more than an eminent professor at Sandhurst.

Academies were established as depositories of learning and practice in the fine arts, and the means of their preservation and transmission through the vicissitudes of the times. The enlightened and commercial Colbert had seen how in Greece and ancient Rome, and in modern Rome, under his own countryman, the Constable Bourbon, a public calamity might disperse and ruin them for half a century, without some fixed and corporate body and abode. He never dreamt that, in the absence of the fostering patronage and employment of government, the Academy could do more than fulfil these negative objects. The Royal Academy had done much more than this—it had sustained the credit of the country in fine art, and had reared talents which were now part and parcel of English history. Through good and evil report it had nourished the flame; and it was consolatory to find that they had transmitted it to better times, through long and adverse circumstances; for now they had the happiness to see two Professors in the Universities of London, the British Institute of Architects, large public patronage in Art-Unions, &c., and a growing interest in the Universities of Oxford and Cambridge towards fine art generally.

But Architecture, as a science dignified by an intimate connexion with the exact sciences, and by her acquaintance with those eternal laws of mathematics and of physics which are obeyed throughout the universe, was, in this Academy, regarded only as a fine art, and these lectures were designed to illustrate Architecture in that capacity alone. Dealing with the phenomena of beauty and ideality in the form and aspect of her contrivances, she becomes an essential member of the fine arts, the more essential since her conclusions are more undefined and remote than any other branches of the fine arts, save Poetry and Music, with whom her nearer relationship than with Painting and Sculpture, is sustained by many. But in all that respects the beauty of forms and their combinations, she must never forget her obligations to her sisters Painting and Sculpture, by whose aid alone she becomes the Ars Regina, and keeps in view her prototype Nature, ever equally solicitous of beauty and of use. And the moment she declines their counsels her proportions become anomalous, and she descends to the mere building art.

In Egypt, where Painting and Sculpture were in comparatively small esteem, and again in the middle ages, proportions were wholly capricious, and subject to no order or regularity; nor have any been ever attributed to them even by the greatest admirers of Egyptian or Gothic architecture. On the contrary, the Greeks, aided by the union of the three arts, soon established that analogy with the organized productions of nature, which fixed the proportions of Architecture in so determinate a form as not to be safely departed from, and which, whether in the days of Phidias, or Raphael and Michael Angelo, or any other renowned period of art, has been approved and adopted as just and incontrovertible.

The fulfilment of the duty of the Professor under a limited number of lectures had been a subject of some anxiety and difficulty. The history of the art was the only safe foundation of the study, and had, therefore, formed his first course. "Architecture," says Sir C. Wren, "is founded on the experience of all ages, promoted by the vast treasures of all the great monarchs, and the skill of the greatest artists and geometricians, every one emulating each other. And experiments in this kind being greatly expenseful and errors incorrigible, is the reason that architecture is now rather the study of antiquity than fancy." With respect to the duration and progress of this art, it might be said that a hundred years were but as a day; being made for ages, it could not, therefore, be subjected to the vicissitudes of fashion; and the slowness of its progress and invention ought to inspire us with respect for antiquity and the authority of example, and to repress that presumption which too often assumes to dispense with them.

In fact, at every epoch in which the art had raised itself to its highest conceptions, we find, not only artists, but theoricians, archæologists, and historians, occupied in describing its progress and inventions, illustrating its monuments, and seeking out its antiquities. There are many histories of Architecture more or less complete; Canina's work promises to supply the history of ancient architecture which Winkelmann had left very insufficient. D'Agincourt's 'Histoire de l'Art par ses Monumens' was an admirable work; it treated of the art, from its decline to its revival and restoration. Durand's 'Parallel des Edifices anciens et modernes,' on the same scale, is highly illustrative of the history of Architecture.

The second course (that of last year) had treated, chiefly, the literature of the art; following out the Academic instruction, namely, "to fit the students for an unprejudiced study of books in the art." It had been well said by a learned

* Very slightly abridged from the *Athenæum*.

prelate, "that we do not live in an ignorant age, but certainly not in a learned one;" and it was painful to see those authors who had been canonized by ages, either attacked and discredited, as Vitruvius, or held to be antiquated and obsolete, as the old Italian and French authors, and, above all, the admirable Alberti, the Bacon of the art, and others of the greatest interest. The obvious consequence was, that new lights, fashionable conceits, and heretical opinions, were conducting us into the large ocean of error. As well might the lawyer or the divine dispense with books as the architect. In the very dawn of literature the architect was required to be learned. In the Memorabilia of Xenophon, Socrates inquires, "But what employment do you intend to excel in, O Euthedemus, that you collect so many books? is it architecture? for this art, too, you will find no little knowledge necessary."

A familiar example of the great utility of these researches had been given in the quotation from Philibert de l'Orme (lib. ii. c. xi.), of the specification for concrete, written in the latter part of the sixteenth century, and corresponding precisely with the recent so-called discovery of this method of securing foundations. During the last century our architects had discontinued the ancient practice, having adopted the most fallacious fashion of wood-sleepers, to the ruin of many fine buildings. It was, then, the ignorance of this invaluable and most instructive and amusing author, Philibert de l'Orme, which had led to so fatal an error.

With reference to Vitruvius, the commentators, in forty-one editions, since his discovery in 1416, were shown to have made but slow progress, and to have done the author but little justice; and ever since the uncandid Schneider had published his edition in 1807, ten important discoveries, illustrating the correctness of his theories, had been made by modern travellers and architects.

In the present course the Professor purposed the consideration of the more difficult, but no less important, injunction of the Academic regulation, "that these lectures should be calculated to form the taste of the students, to instruct them in the laws and principles of composition, and fit them for a critical examination of structures."

Those laws and principles which are technical, were often treated, and were more obvious; but those which constituted Architecture a fine Art, were more subtle, but not less vital, to those who aspired to the higher attainments of the art, namely, the sublime and beautiful. Such inquiries had employed the most learned and ingenious minds in all ages; and although theories are proverbially dangerous things, and must be treated with great caution, yet, recommended as they are by the authority of great names, they ought to be known and discussed; effects attributable to right reason and right feeling are essentially subjects of discussion, and the old proverb should be reversed, and "De gustibus disputandum est" should apply to all those preferences which depend on reason, and not on sexual or fanciful arbitrament; and though the inquiries into the æsthetical of art, which have occupied the last century particularly, fall short of the results we should desire and expect, and that after all genius alone can rightly solve these questions, which elude common sense, yet we may cultivate and improve our critical powers, learn to think more accurately, and correct that colloquial laxity of speech which refers all impressions to some cant phrase of undefined signification, as *fine and beautiful, tasteless,* &c., &c.

Such investigations afford the only means by which the principles of this or any other art can be ascertained, and the artist can be enabled to determine whether the beauty he creates is temporary or permanent, whether adapted to the accidental prejudices of his age or to the uniform constitution of the human mind; and whatever the science of criticism can afford for the improvement or correction of taste must altogether depend upon the previous knowledge of the nature and laws of this faculty.

The development of the human faculties is exhibited in the history of Architecture under its most favourable aspect. The art might be termed the epitome of civilization, the first-fruits of social order and combination, of every discovery in science, and of every conception of beauty. Political history is of comparatively inferior interest, and betrays, for the most part, the depravity of our species. The natural labours of man, those of agriculture or commerce, their unvarying succession, brief endurance, and disappointment, leave melancholy convictions; but in the occupation of Architecture, man finds the employment of those higher aspirations and idealities for which he feels himself born, as well as of his physical energies. Here he perceives that he has a soul; all his loftier conceptions—order, calculation, beauty, and immortality—are opened to his contemplation, and he seems to feel the power of extending his works and his memory beyond the bounds of nature and of time.

The exhibition of these innate and physical capacities seems to be his natural desire; and the progress of his operations coincides with his intellectual growth. In his boyhood he contends with the forces of Nature; he moulds the vast rocks, and rears on end the monolithic obelisk; or, accumulating the masses with laborious endurance in the pyramid, he emulates the works of Nature herself; and exulting in the force of order and combination and his acquired skill, he exclaims, with the Babylonians, "Go to, let us build a city and a tower, whose top may reach unto the heavens, and let us make us a name." And although in our advanced civilization, we may smile at the superfluity of such labours, we must not forget that by them man first vindicated his capacities, and that metallurgy, mechanics, and all the manual exercise and discipline which fulfilled his apprenticeship to civilization, were brought into practice which soon employed itself in more intrinsic benefits.

The age of Alexander and the Romans abundantly illustrated this truth. Man now contends with the elements. The ocean is curbed by his ports, and quays, and Pharos: he sails across its bosom: marshes are drained; sewers, canals, aqueducts, and roads exhibit the mastery he had acquired, and his conquests over nature. Frontinus, whose work on aqueducts was written about the year 80, has a passage remarkably illustrative of the growth of this spirit in his time. After giving a description of the nine aqueducts under his care, brought to Rome by successive labours, making an aggregate length of about 142 miles, he exclaims, "with so many waters, and so many magnificent works necessary for their transport to this great city, will you compare the idle Pyramids of Egypt, or even the inert works of the Greeks, however celebrated and glorious in history?" The ingenuity of the architect now, therefore, issues to use, and through 1800 years it is more or less subordinate to it, either in the great business of religious and moral improvement in the building of churches, or the security of civil life in castles and mansions. Finally, in recent times it is contracted to absolute utilitarianism, and all its powers are bent to the perfection of the individual dwelling between party walls, in which every subject of the state is in the enjoyment of personal luxuries and conveniences of life unknown to the Pharaohs, the Medici, or the magnificent Louis the Fourteenth.

Thus, as Monsieur Guizot finely observes, each age and nation seems to have flourished for some beneficial purpose to mankind, which, being accomplished, it disappears from the stage.

The history of Architecture may be said to divide itself into five classes—Sacred, Civil, Military, Domestic, and Monumental. In the accompanying drawing [a roll about twelve feet square, containing a vast group of buildings inscribed within the outline of the pyramid, on a large scale] are seen indiscriminately some of the principal monuments of all these classes (except the Military), comprising a period of 3,334 years. We may say to the students, in the words of Napoleon to his troops before the Pyramids of Gizeh, "Quarante siècles vous contemplent!"

This arrangement, done under the Professor's direction, about twenty years ago, appeared (he believed) for the first time in the Penny Magazine. A comparative view of the great buildings of the earth, on the same scale, might minister to that false estimate of merit, which is derived from material dimension; but that criterion would vanish before the comparison of renown; and the Parthenon, and other small buildings, as here represented, would abundantly illustrate the preference to be awarded to

The little body, but the mighty soul.

National attachment might excuse his pointing out the spire of the Old St. Paul's, the only one exceeding the height of the Great Pyramid. Those of Mechlin and Cologne, though designed to have exceeded it, remained imperfect. A limit seems to be placed to man's arrogance and vain-glory. We were taught, like the Babylonians, that the God of nature delights not in the accumulation of his favours and his light, in isolated and single spots, but in the wide-scattered communication of them throughout all lands.

But the observations already offered, were illustrated still further by the sections [on a roll as large as the former, showing

the structure of the most important temples on the same scale]. The issue of the art in use and economy, was most remarkably shown in the comparison of those sections, in which we observe, that St Paul's displays the largest bulk with the least material, hitherto contrived.

He should now call the attention of the students to two rolls [about sixteen feet long each], in the first of which tho plans of the remarkable temples of the ancient world, from the Tabernacle in the Wilderness (1491 B.C.) to the reception of Christianity (313 A.C.) and in the second those from that epoch down to 1842, were all laid down to the same scale. There was displayed, as it were, the genealogy of temples, during 3,330 years.

It was Sacred Architecture which he purposed to review cursorily in next lecture; and short enough was the time for a subject so deeply interesting; indeed, such an expression might be deemed presumptuous; and it was obvious that he should be enabled to do no more than pass the plans in review, and remark upon those characteristics which became the more palpable on the synoptic view of centuries and ideas of such extent and variety; and which were less frequently commented upon. It might be objected by the student that subjects of such vast scale and importance and rare occurrence should be illustrated, rather than the more practical; but we should remember the dictum of Vitruvius, that the architect ought to pursue his studies "maxime in ædibus Deorum, in quibus operum laudes et culpæ æternæ solent permanere." In fact, the remains of these precious exemplars of skill and cost and labour, the types of our art, were still discoverable even from the most remote times, as if Nature herself, as well as man, had respected them.

LECTURES ON SCULPTURE.

DELIVERED IN THE ROYAL ACADEMY, BY SIR RICHD. WESTMACOTT.

LECTURE I.

The elementary principles of sculpture and painting (Sir Richard observed) are the same; the same rules are prescribed for the acquisition of a correct view of nature, both as respects character and the harmonious combination of parts. But the application of these principles differs materially in the subsequent practice of these arts. The sculptor cannot imbue his mind too strongly with the antique examples, nor should his attention be diverted from them at any period of its practice. It is equally necessary for the painter to retain and recur to the fine forms of the antique, but he must forget the statue. Sculpture and Painting address the imagination through the same organs; but, as in this address, through opposite materials, very different sensations are proposed, the selection, therefore, of the objects or subjects for imitation should be carefully attended to. The powers of the sculptor are limited, while those of the painter are indefinite. He can recede or advance; he may employ all the machinery of perspective, chiaroscuro, or colour,—in fact, every vehicle within his grasp,—to assist in the great object of his endeavour, which is illusion. The sculptor, on the other hand, is circumscribed by his material; few accessories are permitted him; his art is positive and determinate. Even in basso-relievo, the greatest license which can be allowed in sculpture, the attempt at two planes has never been satisfactorily accomplished.

But illusion is not wholly beyond the reach of the sculptor: the charm of harmony acts so powerfully on the mind, that, by the concentrated unity of the parts, and by a judicious concealment of the mechanism of his art, he may awake the sympathies of the spectator, until he yields to its influence. The sculptor, it is true, cannot produce the varied enjoyment offered by the painter; but in the power of imbodying any passion, separately considered, he has advantages over the painter, from the variety of points in which his subject (unless it be a work in relievo) may be viewed.

We frequently find that different persons see nature through a different medium; and, consequently, vary materially in their transcripts from the same objects; trusting to the impression of their imagination rather than in considering character, or applying the principles in their imitation of nature which they were presumed to have acquired in the antique school: a defect which generally leads to *manner*. It may be asked what this word implies; and why that convention of the Greeks, which in the modern sense would be called *manner*, is, by the learned in Art, called *style*.

Style is the product of a decree; not established by one man, but by an aggregate of talent. It is founded upon nature; and though its elements may not be met with in perfection in any one individual, they are to be produced by compounding the forms which nature supplies, into all the varieties of character which are the best adapted to, and the most in harmony with, the several purposes designed; whether the object is the expression of majesty, of beauty in its various characters, of strength, or of activity. Style must not be confounded with treatment, which has a discriminate application, and must be understood to refer to the appropriate *conduct* of subjects of each class, and not to that distinguishing quality solely which is found to pervade works of most opposite character, as in the Discobolus by Myron, the Fighting and Dying Gladiators, Fauns, Heroes, Mercury and his class, Hercules, and Apollo. The first three statues, as the Discobolus and the Fighting and Dying Gladiators, are quite distinct as far as the style of school is considered; but each possesses qualities common to all as belonging to a class: at the same time it becomes a question, and will be a subject for future inquiry, how far the two latter belong to the first.

The Discobolus of Myron is the representation of a man trained for a particular purpose; therefore the treatment appropriate to it, and all statues belonging to the class of Athletæ, as boxers and wrestlers, is marked by a squareness and compactness of form; by the divisions of the body and limbs being decided; the parts large in their masses; tho bones well marked; the joints clean and defined; and no fat nor unnecessary fleshiness; and the belly especially rather compressed;—great attention will be found to be paid to the head; the hair is arranged in a close order, the forehead compact, the brows well defined, and a general clearness of feature throughout. The ears in statues of this class are small, crisp, and well set.

The Fighting Gladiator, as it is usually called, but more properly by Mr Fuseli, the Warrior of Agasias, differs in some particulars of its treatment from the above-mentioned statue. There is a greater quantity of small parts than seems to be agreeable to the class of Athletæ in general; but it has, at the same time, certain qualities which may be noticed in the Discobolus, particularly in the head, and in the disposition of the parts, and in the proportions so well adapted to agile exercises. My opinion upon the Dying Gladiator, and my reasons for excluding that statue from the class of Athletæ, I shall offer at a more advanced period of my lectures.

The characteristics of the treatment appropriate to Fauns, are a round, healthy fulness of parts, but without fat. The muscles should be tendinous and knotty; the belly not flat and compressed, as in statues of Athletæ, but inclining to roundness; and this character should pervade even the features of the face.

The forms applied by the ancient sculptors to the Hero class, differ again materially from those used in Athletæ. Here beauty, breadth, and strength, are united. He must appear with the powers of a god, without that distinctive quality which makes him, in the ideal treatment of parts, his equal; he must be a mortal; and his nature must appear to demand repose after exertion; I cannot, perhaps, offer to your notice an example which more fully illustrates this than the statue of Theseus in the Elgin collection.

Mercury, though assimilating much in the character of the head with the Athletæ, is distinct in the general form, and may be placed between the Athletæ and the Hero. The Professor proceeded to contrast the characteristics of the messenger of the gods with those of the Hercules, and subjects in which physical power was chiefly developed. In Mercury, he observed, we are struck with the arched breast, the rather narrow hips, and tho light and clean forms of the legs and arms, which denote that precise degree of strength, combined with elasticity, which is compatible with youthful manly beauty; whilst the inflexibility of the neck, the powerful breast, and the massive shoulders, the head small, with crisped hair, the solid features, a steady firmness in repose, and a powerful display of muscles in action, distinguish the Herculean class.

The object of the Professor in offering these sketches of the several distinctions of classes was to render academical studies useful in future practice, and to impress upon the student the necessity of discrimination and careful consideration of character in working from nature. The forms which characterize all the above classes were not dictated by caprice or false conception, but were justly, as well as beautifully, adapted to their several

purposes; and each, though perfectly distinct in treatment, was great in style.

Manner, as opposed to style, arises from a peculiar and distorted view of nature; the result of a defect in, or too often from the absence of, education. A constant communication, therefore, with the antique, is the surest preventive against peculiarities in action, proportion, or expression, which a too frequent recurrence to favourite individual models might insensibly induce.

Equally to be guarded against with *manner*, and to which it is allied, is that of becoming mere imitators; a fault even of worse character, and more directly prejudicial to progression. It returns art, as it were, upon itself; and, keeping it in this respect in a continual state of infancy, errors and theories, which accident or other causes have brought into existence, are thus reproduced, till art loses all its life and energy, and becomes vapid and imbecile.

Speaking of the error of adapting art to the prevailing taste of the day, Sir Richard remarked, that a moment's reflection would show that systems so founded have no existence beyond their own time, or when the temporary ascendancy of local influence or fashion have passed away. The decline of art from the death of Augustus to Adrian, supplies a powerful example of the effect produced by such causes amongst the ancients; and in modern times it may be strikingly exemplified in the works of Bernini and his followers; in the prevailing taste of the French school even up to a very late period; and, with very few exceptions, of Rysbrack and Roubiliac.

By reasoning as you proceed in your practice, you will find Nature a bountiful mistress, and that ideas, infinite and original as her beauties are various, will disclose themselves, which lie concealed from superficial observers. By reflection, you will not only be able early to distinguish false from true character, but acquire a proper confidence in your own powers, and learn that a departure from the accepted course to excellence has proved as vain as it has been delusive.

In the Arts, but in Sculpture more especially, the necessity of a standard whereby the artist could not only regulate his forms, but apply his mind to the most effective mode of expressing the images presented to it in masses, consistently with the limited nature of his materials and circumscribed sphere of their application, appears to have occupied the attention of the Greeks at a very early age, and to have been constantly exercised by them throughout the best periods of Art.

The distinct properties of forms, and their application to the several offices or purposes for which they were designed, being established upon nature, and obvious to the common sense and common feelings of mankind, left no doubt, admitted of no appeal; and a principle thus based upon truth, became with them immutably fixed. Fashion usurped no tyrannical sway: no love of mere novelty was allowed to exercise its baneful influence. The wisdom of the Greeks—and it was the cause of the progress in Art with them—consisted not in endeavouring to find out *new* systems, but in communicating the utmost degree of perfection to those which already were established; and no artist could hope to raise himself to notice by any new theories, or by departing from the admitted rules of Art.

The Fine Arts in Greece, and in almost every other country in which monuments are found, appear to have had an independent origin; but their history, even in Greece, is involved in the greatest obscurity. With few exceptions, until the 30th Olympiad, or 650 B.C., when a more mature system in Art became evident—and the artists accommodated themselves to the progress of science and of civil institutions—the state of that country affords little information either to the antiquary, the historian, or the artist.

But although the arts sprung almost everywhere out of the same causes, their progress was advanced or obstructed, in a great measure, by the character of the political institutions of the several countries.

If wealth, long periods of peace, and, at the same time, constant practice in Sculpture, could have operated in bringing this art to perfection, no country was more happily circumstanced than Egypt. But, restricted by their government—a consolidated hierarchy—their attachment to consecrated ideal forms prescribed models from which no artist could safely depart. The same character of features may be traced, with few exceptions, through all their works; and we see the same unvaried style of composition from the commencement of their art until its extinction. The effect of these restrictive laws is strongly instanced in the personification of their deities and kings. They were not permitted to avail themselves of those advantages, which the practice of embalming constantly offered them for the examination of the construction of the human body; and we therefore find their figures eminently deficient in anatomical correctness. It may be presumed, from the science and skill displayed in their representations of animals, that the same restriction was not extended to representations in this branch of Art. As examples of the ability with which this class of subjects was treated, it will be sufficient to refer to the two lions in front of the Fountain of the Termini at Rome, a sphinx which is at Dresden, and the lions presented by Lord Prudhoe to the British museum. These works are remarkable for expression, and they display also considerable anatomical knowledge. The latter, indeed, exhibit a degree of truth, and grandeur of form, equal to anything we find in that branch of Art by the Greeks; and they are strong proofs that that pure, simple, and consistent principle on which the power of nature rests, was sensibly felt by their artists, and acted upon, when they were not cramped by rules prescribed by their priests, and which it was a species of sacrilege to transgress.

No country possesses more perfect specimens of Egyptian art than are to be seen in the British Museum; and we are indebted to the late Dr Young for much valuable information and elucidation on this subject.

From the concurrent hieroglyphical representations contained within the orbs or shields expressing symbols of their deities, and the names and titles of their kings, we may ascertain the dates of several monuments. The fact of the statue of black granite in the British Museum, discovered by Mr Salt near the vocal statue of Memnon, having names and titles sculptured on several parts, and being similar in other respects to that Colossus, leads us to the belief that it is the representation of that king; and that consequently we may fix the date of the work at the period assigned to Memnon—namely, at 1700 B.C.

A specimen of early Egyptian art may be seen in the statue of the young Memnon (as it is generally called) in the British Museum. There is a sweetness of expression in the head, and a breadth and simplicity throughout the whole of this work, which make us deeply lament the trammels by which their artists were confined, and which prevented them from giving a fuller development to the feeling which evidently only wanted opportunity to display itself in works of great beauty.

We occasionally find great beauty and sharpness of workmanship in the sculptures of Egypt, even when the hardest stones are employed. The lions before alluded to, in the British Museum, display the artist's skill in producing a soft and undulating surface in a very hard and almost intractable material; and which is the more surprising, as we have no reason to believe the Egyptians had any very extended knowledge of metals, nor of the mode of tempering iron instruments, to adapt them to such difficult and trying work.

The head of a sphinx, probably of the same age, still existing at Thebes, is spoken of also as a work of admirable execution. It is of colossal dimensions, being seventeen feet in length, and fourteen in height. Their knowledge of basso-relievo was considerable; and a greater degree of intelligence and attention was displayed in such subjects, both as to form and in the articulation of the joints, than in their detached statues. This is very observable in their kneeling figures, in which the oblique muscles, those of the abdomen, and the pressure of the gastrocnemii, or muscles of the calves of the legs, against the lateral muscles of the thigh, show much knowledge and careful study of nature.

The Professor here made a few general observations on the character of Egyptian art at different periods. Of its infancy, he truly remarked we have no power of judging; its history is lost in the impenetrable darkness of antiquity. It has usually been classed into three periods; but that attachment to consecrated forms directed by the priesthood, was at no time entirely departed from; and the same Ethiopic features may be traced through all their works; and, with few exceptions, the same unvaried compositions will be observed from their commencement until their fall.

The first period has been dated from the age of the Pyramids or Obelisks to Cambyses, comprising 1500 or 2000 years; during which works were produced of extraordinary diligence in execution, though varying in several instances in the workman-

ship. In no respect, however, are they found to depart from the general forms prescribed in the configuration of their deities.

From the period of the conquest of Egypt by Cambyses, and under the successors of Alexander, the same care and attention do not appear to have been observed, nor was the same regard paid to the choice of material.

The subsequent period, or that from the extinction of the Ptolemaic dynasty to the reign of Adrian, can scarcely be styled one of indigenous art. The only distinctions we observe during this period are, the more or less careful execution; the forms and taste were the same. The Professor here described the character of the first period of Egyptian art. The first thing we observe is the want of articulation in the joints; the hands and feet are without markings; all is straight and elongated, and even the little toe extended to an equal length with the others. The eyes are flat, and project as far out as the superior bone of the orbit; the ears are placed high, the lobe being on a level with the eyes; the nose is flattened, and the lips are thick. Another peculiarity of the earlier period of art is, the flatness of their works in relief.

Towards the 6th century B.C., the style both of sculpture and of architecture became debased. Euergetes II. erected several temples; but the majesty of Egyptian architecture was lost in the exuberance of ornament, which, as may be exemplified in Greece and Italy, always accompanied the decline of the arts; and their downfal from that period does not appear to have been for one moment arrested.

Of the Etruscans many and conflicting opinions have been offered, and their origin is still uncertain. I shall, however, adopt the generally received opinion, and consider them as a people of Pelasgian origin.

Their first emigration from the Peloponnesus is generally stated at 1200 years B.C.; that during the interval of the second emigration other colonies had settled in Etruria, and had brought other fables and legends, is highly probable.

The general character of art introduced by the first settlement is, however, tolerably distinct. In the heads of their figures the eyes will be found to be angular; the countenance rude and ill-formed; the fingers and toes long; the feet ill-placed; and but little attention was paid to proportion. The advantages which this people enjoyed from a long period of peace, at the time when Greece was a prey to frequent revolutions, was favourable to their cultivation of the arts; but left as they were to their own rude conceptions, they appear to have made little progress in them.

The gem now to be seen in the king of Prussia's collection, and which was formerly in the possession of the Baron Stosch, commemorating the event of the Argive league against the Thebans, is the oldest known to exist. It is generally considered to be a specimen of the art of that age.

An example of the latter part of this period may be seen in the basso-relievo of Leucothea, in the Villa Albani, in which there is much similarity in the erect position, parallel lines, flat and angular drawn-up eye, to the Egyptian manner; whilst the treatment of the hair and other parts of the composition, remind us much of the early Grecian coins.

That the Etruscans were assisted in their progress towards good taste by the second emigration, which is placed at 600 B.C., is highly probable. There is a marked distinction at this period in Etruscan art—a greater knowledge of, and attention to, grouping and expression; and the subjects of their chisel were chiefly selected from Grecian fable.

In the second epoch of Etruscan art, so much of the early Greek character was mixed with it, that the most skilful antiquary is often at a loss to distinguish them; indeed, the whole may be considered as a class. There is, however, a distinction: the rude forms and short proportions of the earlier school were now changed to the opposite extreme; there was no grace, but attempts at musculation and expression were carried to excess.

This artificial manner may be seen in their relievi. We have few statues well authenticated; but their intagli are safe guides, and that of Tydeus, of which the execution cannot be surpassed, is a good specimen.

In the third period, if it may be so termed, their sculpture is wholly undistinguishable from early Greek art. This style or character continued until Etruria lost her liberty, and became amalgamated with the rapidly growing empire of Rome.

AGRICULTURE.

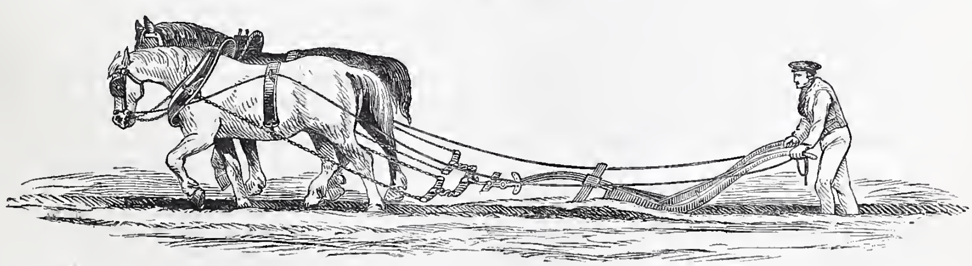
CHAPTER VII.

MANAGEMENT OF A FARM DURING WINTER.

Winter is a busy time for the farmer. In addition to many minor matters, he has, in this season, to attend more than usual to ploughing, to thrashing corn, to storing turnips and fattening live stock, to forming dunghills; and at this season, also, his work-horses receive a somewhat peculiar treatment. Each of these demands a little separate attention.

PLOUGHING.

The end attained by ploughing is twofold: first, to render the ground friable, so as to receive either manure or seed, or both, as the case may be; and, secondly, to break up a small portion of the subsoil, to compensate for that portion of the upper soil that has been carried away by previous crops. The common plough used in the improved districts is now constructed wholly of iron, its weight being perhaps fifteen stones. It essentially consists of a beam, to which the horses are yoked, a coulter that severs the slice from the firm land, a share that cuts the slice below from the subsoil, a mould-board (made of iron) which receives the slice from the share, and turns it over, and disposes of it at an angle, in the best constructed ploughs, of forty-five degrees, and the handles or stilts, by holding which the ploughman steadies the plough. It is pulled by two horses, working abreast; and besides holding the plough, the ploughman drives the horses. This last he does by means of two cord reins and his voice. He has no whip. Between



the horses and the plough the swing-trees intervene. The part of the beam to which the swing-trees are joined, is so constructed as to enable the ploughman to make one horse have to pull more than another. As horses are frequently of different powers of draught, this is very essential. The harness of a plough-horse consists of a collar (without a cape, which is a useless encumbrance,) having a bridle, a back band, and chains, the whole weighing only 38 lbs.*

The grieve instructs the ploughman as to how deep the furrow slice, as it is called, is to be made. Seven inches is a very good, and ten a great depth. Sometimes, in ploughing, the instrument has a tendency to go too deep. To obviate this, if pressing down the stilts be not sufficient, or too fatiguing, the parts about the beam are so constructed that, by

* It will, of course, be remembered that we are speaking of those parts of the country only where the most improved system of agriculture is followed.

changing the place of a bolt, the point of pulling may be brought higher up, and *vice versa*. It is in doing this, or "tempering his irons," and in taking care that the slice turned up be rectangular, not trapezoidal, that the art of good ploughing consists. The furrows must, indeed, in addition, be quite straight, and the slices should lie over at an angle of forty-five degrees.

The quantity of land that can thus be turned over in a day by a good ploughman and a pair of horses varies according to the soil, the size of the field, (the more turnings there are, of course there will be the more delay,) &c., but about an acre may, perhaps, be taken as an average. This will imply about thirteen miles of walking for the man and his horses.

The field is divided into ridges usually eighteen feet in breadth, and, if possible, running north and south, so that the crop may receive the sun equally.

In practice, the stubble land, *i. e.*, the land that has borne corn, is first ploughed, and then the lea land, or that which has had the previous year a crop of grass. Of the stubble land, that part intended to bear beans and peas is first ploughed, then that intended for potatoes, and lastly, that where the turnip crop is meant to be.

It requires the greatest judgment on the part of the grieve as to how soon to allow clay land to be ploughed after much rain. If this be done too soon, large clods are turned up, which afterwards become perfect bricks.

THRASHING.

In a farm of mixed husbandry there is, during winter, a great demand for straw, both for litter and food. To meet this requires frequent thrashing. At the commencement of winter, the farmer, by preference, thrashes barley, inasmuch as it is during this season that the demand (for malting and distilling) for this cereal most prevails. But he must also thrash his other crops, both for other reasons and for this, that barley straw is not relished by cattle as fodder, and that therefore he must have due supplies of straw of other grain.

In improved districts, thrashing corn is invariably done in a thrashing-mill. If a supply of water can be procured to turn this that can be depended upon, this forms the best motive power. If that cannot, a small steam-engine should be erected. Still horses are often employed to turn it, but never wisely; for turning a thrashing-mill is very destructive work to horses, and, besides, sadly impedes field labour. At one time, wind was employed to turn the mill for thrashing corn, but such windmills have gone quite out of use, and there is not, perhaps, now one in existence. The reason for their disuse is doubtless the uncertain nature of the motive power.

Without many illustrations, it is impossible to describe the thrashing-mill. It must suffice to say, that it separates the grain from the straw most effectually and economically, far more so than the old practice of hand-thrashing, which, besides, entailed very severe labour upon the farm servants. Besides being thrashed, corn requires to be separated from impurities to fit it for the market. This is done by the process of winnowing. Now, frequently the same motive power sets in motion both the thrashing and winnowing apparatus.

In addition to thrashing and winnowing, barley requires hummelling, as it is called, that is, a portion of the awns often stick to the grain, and require to be separated. This is done in a *hummeller*, which is either driven by the same power as the mill, or by hand. Small farmers sometimes use hand-hummellers.

Corn, when thrashed and *well* winnowed, is ready for the market, and only requires, before being sent thither, to be measured, weighed, and put into sacks. In the districts to which we more particularly refer, it is sent thither in one-horse carts, every two carts being under the charge of one man.

PULLING AND STORING TURNIPS.

If the history of some of the most successful farms be investigated, it will be found, that after a struggle, in which very small profits were made, it was determined to raise a crop of turnips, by means of bought bones, and to consume these turnips upon the ground with sheep. From doing this, we will learn, the fertility of the soil and the prosperity of the farmer are to be dated. If land that is not very heavy be well dosed with bones, a good crop of turnips may be relied upon, and if these be ate off with sheep, the barley crop and the grass crop that succeed are sure to be good ones, and increased fertility of the soil still remains. Now, indeed, that we possess guano and other portable manures, we are a good deal independent of this source of fertility; but still, except in the neighbourhood of large towns, it is found a profitable plan to consume a portion of the turnips on the ground with sheep. Generally speaking, one-half is so consumed, but if the land is in low condition two-thirds, and if, on the contrary, the soil be in very high condition, only one-third is so eaten. When the half is going to be consumed by the sheep, two drills are lifted and carried away, leaving two drills together. The sheep are then confined to a portion of the field containing the half crop that is left, by means of either hurdles or nets, and when they have finished the turnips on this place, they are removed to another, and so on until the whole field is finished. The portion surrounded by nets, where the sheep are eating, is called a break.

It is the custom on too many farms to pull and take away for consumption in the steading, as many turnips at a time as will only serve for two or three days' consumption; but this indicates very bad management. One inconvenience of it is this; if a severe frost or snow set in, an imperfect supply is expensively obtained, and the cattle fall back. Another is, that such a plan of procedure implies the necessity of going with, and working horses and carts upon the land after thaws and heavy rains, and thus give it a poaching that will tell most severely upon the next crop. Opportunity should be taken during fine weather, when the ground is firm and dry, to lay up a large store.

Upon an opportunity like this, the whole staff of field labourers are set to. Each worker takes charge of two drills, lifts the turnips, cuts off the roots, and usually the tops, and throws them into temporary heaps between the two drills that are left. Some farmers feed the young cattle with the tops, while others leave them to rot upon the ground and be added to the soil, from the belief that they injure the calves and young stock owing to their purgative nature. Carts then come, into which the turnips are thrown by hand. These convey them to the store, which is some convenient bit of ground in or near the steading. They are placed upon the ground, covering a breadth of about ten feet, and a length, of course, in accordance with the quantity lifted. They are piled up in a triangular shape, and between the apex and the base about four feet of height will be found to exist. They are then covered over with straw, to protect them from the frost, and the straw is kept in its place by straw ropes that pass over it, and which are fastened to the ground with pegs. Whenever turnips are wanted, this straw is turned aside, and the requisite quantity taken out.

THE WINTER FEEDING OF SHEEP UPON TURNIPS.

The sheep, as we said, are confined to a break, by means either of hurdles, or nets fastened to stakes that are driven into the ground, the latter being the better plan. The tops of the turnips do not in general injure the sheep, but, if the break be made too large, they eat too many of them the first day or two, and suffer from it. The ewes, we should observe, are never put upon turnips, as, if they are, they become too fat, and, in consequence, produce both small lambs, and are very apt to suffer from inflammation at lambing time. In the break there are always one or two racks filled with either hay or oat straw, which the shepherd takes care to keep replenished. The top of the rack is made of wood, and prevents any rain getting at its contents. There are also a number of troughs provided. These are filled from time to time with sliced turnips. A turnip-slicer, with wheels that enable the worker to move it from place to place, is used for this purpose. But whole turnips are left, and the sheep please themselves as to what proportions of hay, sliced turnips, and whole ones they take.

It is now very common to put, in addition to the above, covered troughs containing bruised oil-cake or corn. This is

generally done when the animals are getting nearly fat enough for the butcher.

There can be little doubt but that much of the fat of sheep is wasted by being consumed to keep the animals warm. Accordingly, it is always contrived that sheep get as much shelter as possible, and perhaps even then they do not get enough. But the plans recently proposed of stall-feeding, we consider, in the meantime at least, impracticable, and, besides, of very doubtful utility.

FATTENING CATTLE IN WINTER.

Three modes exist of fattening bullocks in winter. One is, to put the animals in open courts, well littered with straw. Another is, to keep them in hummels, as they are called, which is essentially a small court with a shed, where the animal can go for warmth and shelter at its will. The third is, to confine them in stalls in byres. In both these last cases plenty of litter is afforded. Box-feeding, &c., are merely modifications of this last-mentioned mode, without litter. It is almost a settled opinion in the districts to which we have all along particularly referred, that the first plan and the last are essentially bad ones. Which of the remaining two is better, is difficult to say, but hummel-feeding, or processes analogous to it, are far more extensively used than stall-feeding.

The two kinds of food that form the foundation of cattle-feeding in winter are turnips and straw; and the former are, by good feeders, almost universally sliced, and the custom of mixing these with chopped straw is become, and deservedly, a common one. Bruised oil-cake and bruised corn are frequently —indeed, the former very frequently—added towards the close.

The great essentials in successful fattening of cattle are, comfort, warmth, variety and plenty of food, combined with perfect regularity of times of feeding.

The manner in which a cattle-man arranges his work, in a mixed husbandry farm, during a winter's day, in the districts we have often referred to, may be interesting. It will, of course, vary, according to the habitations of the stock, whether hummels, or courts, or byres. We will suppose—what is, indeed, a very common plan—that the farmer's cows occupy one byre, in which they are individually fastened by the neck, the servants' cows another, the oxen live in hummels, and also the young heifers and the bull, and that the calves and one-year old animals are in open courts. The cows, we should observe, do not, in general, get as many turnips as they can eat, but, of course, the fattening animals do; the young animals and bulls fare, in this respect, pretty much according to the year's crop, getting as many turnips as they can eat when the crop is good, and wanting them when it is scarce. All, of course, have as much straw as they can consume.

In the depth of winter, the cattle-man's labours begin at dawn of day; if, however, day break before five o'clock, he is not expected to start till then. Before coming to his work, he takes his breakfast. The first thing that he does is to go to the farmer's cow byre, and remove any dung about the animals' hind quarters into the gutter, so that it may be all clean for the dairymaid to come and milk them. He then performs the same office for the servants' cows, to prepare them, in like manner, for the servants' wives to milk; and in both cases he provides for the admission of fresh air into the byres by opening the upper door, or attending to the ventilators, when such exist. He then goes to the fattening bullocks, and carefully cleans out their feeding-troughs, and then replenishes them with sliced turnips. He next proceeds to the court where the calves live, cleans their troughs, and puts them what amount of turnips he is to furnish them with. He afterwards does the same to the one-year olds and the bull. It is unusual to give the heifers in calf any turnips in the morning.

His succeeding duty is to go to the straw barn and take a sufficient quantity of oat or wheat straw, and take it to the byres. He supplies each cow with some of it, and, while they are eating it, wheels away all the dung and dirtied litter to the court. When this is done, he goes to the straw barn and gets some barley straw, and beds the beasts up comfortably. Then he apportions to each cow the quantity of turnips she is to have. The servants' cows have rarely turnips at all. The heifers in calf then receive, generally, a very small supply of turnips. The cattle-man's business after this is to clean out and replenish the fodder of the hummels and courts, and also to furnish their inmates with a plentiful supply of litter. He then goes to the byres, where the cows have finished their meal of turnips, unlooses them, and drives them into a court where there is water. Here he leaves them for an hour, to drink, take exercise, and rub and lick one another. If the weather is so bad that they cannot get out, they must be currycombed. After he has set the cows at liberty, he proceeds to the hummels of the fattening cattle, cleans out their turnip troughs, and gives them a second supply of sliced turnips, and whatever else he is ordered to feed them on. By now his own dinner-time will have come, and for this the cattle-man is allowed an hour.

When he has thus fed and rested himself, he comes back again to attend to his quadrupeds. His first duty, then, is to go to the straw barn, and make up as many little bundles or whindlings of straw (each weighing about ten lbs.) as there are cows in the byre. He places them in the byre to serve against night, in order to prevent being obliged to visit the straw barn with a light. He, in the meantime, furnishes their racks with fodder, and then brings them in. He then proceeds to the courts and hummels, takes the old fodder from the racks, and throws it about for litter, and, moreover, brings as much more fresh litter as he judges necessary, in order to render his animals comfortable. By the time this job is finished, it is time to give the cows a second meal of turnips, that they may have it finished before the dairymaid comes at dusk to milk them. Then comes the time for giving the fattening beasts their third full meal, and the calves and young cattle their second. The young heifers and bulls likewise receive their stinted allowance. Due care is always taken that the last-mentioned have an abundant supply of straw. He now litters the cows, and then rests until eight o'clock. His last duty, at this hour, is to give the cows the whindlings of straw he has provided in the byre, and to visit every hummel and court to see that all is well.

THE FORMATION OF DUNGHILLS.

Drains should proceed from the byres, stables, hummels, and courts, all of which should converge in a well-constructed liquid manure tank. But, in practice, upon the farms of mixed husbandry, where there is plenty of litter, very little fluid finds its way into this receptacle. What does should be mixed with twice the quantity of water, and applied to some crop, preferably to a little Italian rye-grass, growing near the steading, for the purpose of being cut for soiling.

The manure from the courts, hummels, &c., requires to be removed from time to time. It is carted to the fields where it is intended to grow beans, potatoes, and turnips. A dunghill is first formed in the bean division, then one in the potato, and lastly, one in the turnip, as it is in this order that they will be required. The dunghill intended for the last two crops is covered with earth, to prevent fermentation when spring begins to increase the temperature.

For this carting of the dung frosty weather is selected, partly because there is then less chance of exciting fermentation, partly because of not poaching the land, and partly because the men can then be employed without stopping the ploughing.

The roofs of courts, &c., should always be provided with efficient water-spouts, to prevent the rain washing out soluble portions of the dung.

Formerly, much attention was paid to making compost heaps of road-scrapings, weeds, dead leaves, peat, lime—in fact, anything the farmer could lay his hands on. This is still done, but, since the introduction of guano, it does not occupy the prominent place that it used to do.

THE TREATMENT OF FARM-HORSES IN WINTER.

A good deal of difference prevails, even in the districts to which we particularly refer, with regard to the winter treatment of farm-horses. The following is, perhaps, the most common. Each pair of horses, we have to repeat, is under the charge of a ploughman.

The ploughmen rise before daybreak; the steward goes with the stable key, which has been in his charge all night, and opens the stable door; the ploughmen then unloose their horses, who then, of their own accord, go to the horse-pond to drink. One man, however, accompanies them, to see they do not loiter, but return to the stable when they have drunk. If the pond be frozen, the steward will have previously given orders to have the ice broken. During the horses' absence the men remove all the litter, and the steward either delivers out to each man the allowance of corn for his horses, or he himself places it in their mangers. This allowance is usually a full feed, or nearly four lbs. of oats per horse. The stall collars are then put round the horses' heads, and they are allowed to eat their feeds in peace. While doing this, the steward and the men go to their own breakfasts. (This, we may observe, invariably consists of porridge, with either milk or beer.) On their return to the stable they harness their horses, and proceed to their work until mid-day.

They now return to the stables. The harness is removed, (they get a drink of water as they pass the pond,) the steward delivers to the men the corn for their horses, (often, at this time, only a half feed,) the horses are fastened to their collars, and the stable door shut. The ploughmen then go to their own dinners, consisting, usually, of bread, broth, and potatoes. They return to the stable a little before one o'clock, when they wash down their horses, comb their manes and tails, and put on the harness. Whenever it is nearly one, the steward announces it, the bridles are instantly put on, and the ploughmen and horses start for their work.

At this season of the year, the horses are unyoked about four o'clock. As they pass the pond they get a drink, and are made to walk through it, in order to wash the mud from about their feet. They then enter the stable, have the harness taken off, and are well washed down with the straw. After this washing down is over, the men go to the straw barn, and each brings four whindlings of bean or wheat straw, two to serve for fodder now, the other two for later in the evening. Sufficient littering straw is likewise brought from the barn, to render the horses able to lie down comfortably. The horses are now left until eight o'clock, the men, in the meantime, occupying themselves as they please.

At eight o'clock the steward summons the men, by a bell, or otherwise, to come to groom and feed their horses. Lights are placed up and down the stable, and the spectator may well admire the wonderful chance by which the whole building escapes being set on fire, as the lights are commonly without protection. The horses are well curried, washed, and brushed, and their feet picked clean, and, if necessary, stuffed. Their litter is well shaken up, the steward delivers out the allowance of corn—often, again, a half feed, in consideration of the little labour and short hours they now have—the straw is put in the rack, and the animals left for the night, the steward locking the door and taking charge of the key.

On one or more nights of the week, instead of the half feed of oats, the horses get a mash consisting of the same quantity boiled along with turnips, &c.

Crushing the corn, particularly for aged horses, is found the most economical plan of using it, but it is too little practised.

ILLUSTRATIONS OF MECHANICAL DRAWING.

To Delineate a Six-Sided Prism.—For our next general example, a regular six-sided prism shall be delineated. It is rather more complex in its outline than the six-sided pyramid, which was taken for an example in last article, page 270, as it presents a greater number of angles, and consequently also a greater number of straight lines. The hexagonal prism, however, is bounded entirely by plane surfaces, and is easily executed.

Fig. 1. *Fig.* 3. *Fig.* 5.

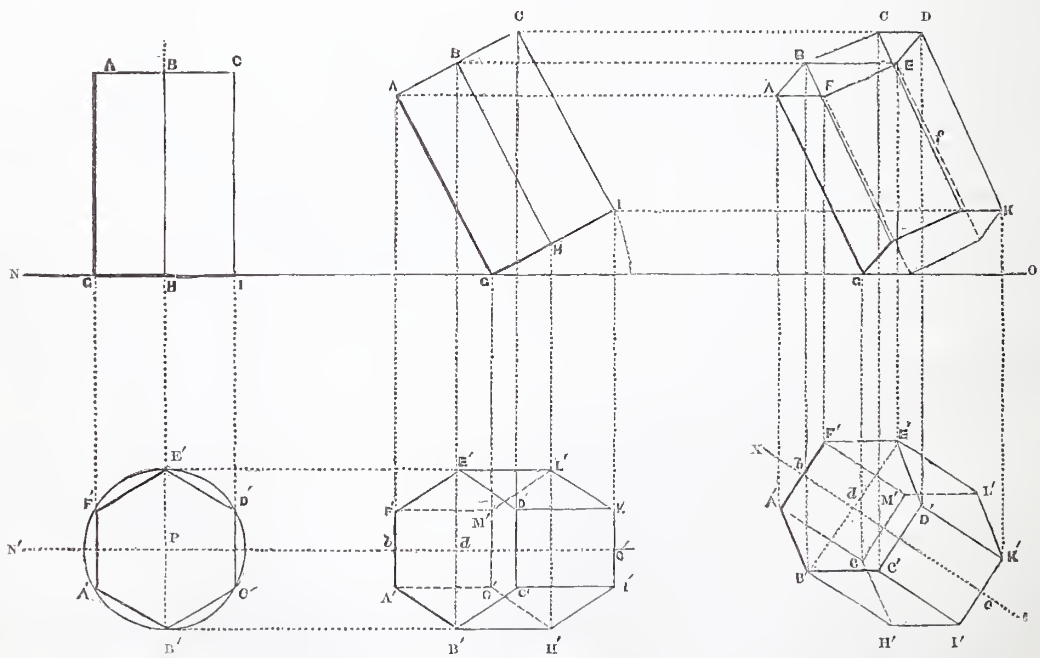


Fig. 2. *Fig.* 4. *Fig.* 6.

The first thing to be done is to draw a datum or ground line, N O, fig. 1, as in the former example, upon which the elevation is to be erected, and a vertical line B′ B, intersecting the datum line at H; this, being employed as a centre line, fixes the position of the elevation. At a convenient distance below N O, draw a second line, N′ O′, parallel to the first, cutting the vertical at P, fig. 2. This point will fix the position of the plan, and the line N′ O′ will be a common centre line for the figures 2 and 4 in plan. Upon the centre P draw a circle as before, embracing the angles of the hexagonal figure in plan; from the centre E, with the same radius, mark off upon the circle the points F′, D′; draw the lines F′ A′, D′ C′, meeting the circle at A′ and C′, and join A′ B′, B′ C′, D′ E′, and E′ F′. There will thus be formed a representation in plan of the hexagonal prism. This plan might have been constructed otherwise by means of the triangle of 30°, for, having fixed the edge of the square parallel to N′ O′, by sliding the longer side of the triangle against that edge till it falls upon the points E′ and B′, the four sides meeting at E′ and B′ may be drawn, and thence the remaining sides A′ F′, C′ D′.

To draw the elevation, fig. 1, we are first to find the points G and I, which constitute the limits of the base of the figure, by setting the edge of the square to the lines A′ F′ and C′ D′; and as the edges of the prism are all parallel, we have only to produce the lines F′ G and D′ I upwards to A and C; and having marked off the height G A of the prism, a horizontal line A B C drawn through A, and meeting the other lines at B and C, represents the upper end of the figure, and completes the elevation. It will be observed, too, that the lines A G and C I are projections of the lateral planes A′ F′ and D′ C′ of the prism, and thus only two of the vertical planes, namely A′ B′ and B′ C′, are seen in fig. 1.

The elevation might have been drawn independently of the plan by marking off the distances H G, H I, equal to the shortest diameter of the prism, and then proceeding as before.

Let us now suppose the prism so far turned over on its edge at G. To represent this, having fixed upon a convenient point G, fig. 3, draw G I for the inclination of the base with the horizontal line; make G I equal to the distance G I, fig. 1, and on the middle of that line erect a perpendicular H B for a centre-line, and draw the parallels G A and I C; set off the height G A and draw the line A C parallel to G I, to complete the figure. The vertical projection of the figure being thus determined, the horizontal projection, fig. 4, will be compounded from figs. 2 and 3. Thus, by drawing the lines E′ L′ and B′ H′, figs. 2 and 4, parallel to N′ O′, they should still define the limits of the vertical edges E′ and B′ in the horizontal projection of fig. 3, as the change of position is made in a direction parallel to the line N′ O′; so also the parallel lines C′ I′ and D′ K′ include the positions of the edges C′ and D′. By drawing therefore the perpendiculars A A′, B B′, &c. from the several points in fig. 3, and meeting the corresponding parallels drawn from fig. 2, this defines the positions of the angles in the plan fig. 4. The points of intersection being joined, they form the polygon A′ B′ C′ D′ E′ F′, being the horizontal projection of the upper end of the prism, and the polygon G′ H′ I′ K′ L′ M′, which is that of the under end. It is obvious that all the edges are projected in equal lines, E′ L′, D′ K′, &c., and that the sides A′ B′, D′ E′, &c. are parallel, as are also the sides B′ C′, E′ F′, &c. These conditions afford a means of verifying the accuracy of the drawings.

To vary the position of the prism still further, suppose it to be turned round from the position in fig. 4 to the position in fig. 6. It will be observed, as before, that this alteration of position does not alter the nature of the horizontal projection fig. 4, and that having determined the position X X of the axis of the prism, figure 6 should be an exact copy of figure 4. To accomplish this, we shall in the first instance mark off upon X X a distance *b c* equal to A′ I′, fig. 4; then draw perpendiculars to that line, A′ F′ and I′ K′, at the points *b* and *c*, making *b* A′ and *b* F′ equal to *b* A′ fig. 4. Again, drawing B′ *d* E′, fig. 4, and setting off the distance *b d* fig. 6, we have then to draw a perpendicular B′ *d* E′ through *d* in the last figure, and set off *d* B′ and *d* E′ equal to *d* B′ or A′ F′, fig. 4. Through the points B′, A′, F′, E′, draw the parallels B′ H′, A′ I′, F′ K′, and E′ L′; join F′ E′ and A′ B′; and as the other sides are parallel to these two, we may draw through the points B′, H′, M′, three sides parallel to F′ E′, and through the points E′, L′, G′, the remaining three sides parallel to A′ B′.

Now the vertical projection fig. 5 of the prism in this position will be found by means of the two figures 3 and 6. For by drawing a horizontal line A A from fig. 3, and a vertical A′ A from fig. 6, their intersection at fig. 5 is the position of that part of the prism. In like manner, by drawing the verticals from the other points in fig. 6, meeting the corresponding horizontals in fig. 5, the intersections of these lines being joined, there will be formed the complete vertical projection of the prism in its doubly inclined position.

The Penetrations of Solids.

In the minor details of machinery, there are numerous instances where one part appears to be fitted or metred upon another, and sometimes one portion seems to be penetrated or completely passed through by another. All such appearances of the interruption or penetration of parts one by another, may be denominated the *penetrations of solids*, and the lines of intersection where these solids meet and run into one another are the *intersections* of the solids. The importance of these cases from their continual occurrence demands for them our careful attention, and we shall before going further, offer some general examples of the kind, by means of which the intelligent student will be able to draw down any other case of the same nature that may occur.

Fig. 7 *Fig* 9.

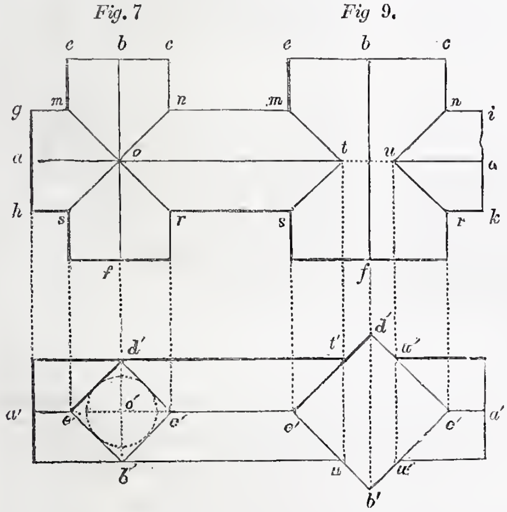


Fig. 8. *Fig.* 10.

Fig. 13. *Fig.* 11. *Fig.* 14.

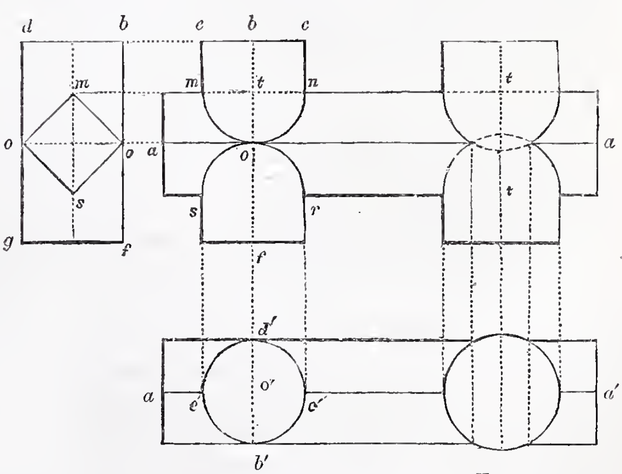


Fig. 12. *Fig.* 15.

Penetration of prisms at right angles.—Figs. 7, 8, 9, and 10, represent the intersections of square prisms, crossing at right angles, and running diagonally into each other. *a a* fig. 7, is an elevation of a prism lying horizontally; *b f* is an upright prism of the same dimension at the ends or sections, crossing *a a* at right angles. In proceeding to delineate these figures, the horizontal centre lines *a a* and *a′ a′* having been laid down, and the vertical centre line *b b′* drawn, intersecting those lines at *o*, *o′*, a circle is in the first place described on the centre *o′*, with a diameter equal to the breadth of a side of the prism; to this circle, tangents being drawn by means of the triangle of 45°, the upper end of the prism, *b′ c′ d′ e*, is formed by them. This figure being also the base of the horizontal prism, will represent also the angles of that figure, and by drawing lines through the points *b* and *d′*, parallel to *a′ a′*, and perpendicular lines at *a′*, *a′*, a horizontal projection of the intersecting prisms is completed. To construct the vertical projection, fig. 7, from this, vertical lines are carried up from *a′*, *e′* and *c′*. It is obvious that the projection of the prism *a a* must be the same as *a′ a′*, and we have only to set off *a g* and *a h* equal to *o′ b′*, and through the points *g*, *h*, draw the horizontal lines *g i*, *h k*. Now, in regard to the intersection of the prisms, the edges *a o a*, and *b o f* will

cross each other without interruption, whereas the edges $g\,m$ and $e\,m$ vanish at the point of meeting m, resolving themselves into a third straight line $m\,o$, proceeding directly to the point o. The same occurs at the other angles n, r, and s. It is easy to see that $m\,o$, $n\,o$, $r\,o$, and $s\,o$ are straight lines, as they are the lines formed by the meeting of two flat surfaces: $m\,o$, for example, being the line at which the surfaces $a\,g\,m\,o$, and $b\,e\,m\,o$ meet. It is, moreover, obvious, that $m\,o\,r$ and $n\,o\,s$ are diagonal straight lines at right angles to each other, and that they may be at once described by the aid of the triangle of 45°, set upon the edge of the square to the point of intersection o.

In fig. 9, we have the same horizontal prism cut through by the prism of larger dimensions $b\,f$, the end of which is presented in fig. 10, $b'\,c'\,d'\,e'$. Here the lines of intersection are the same as those in fig. 7, though they are parted in two. Having drawn the plan of the prism, $b'\,c'\,d'\,e'$, fig. 10, upon the horizontal prism $a'\,a'$, it is seen at once that $a'\,a'$ vanishes on both sides of the centre line $b'\,d'$ at the points t', u'; carrying up the perpendiculars $c'\,e$, $t'\,t$, $b'\,b$, $u'\,u$, and $c'\,c$, the points t, u, in the centre line $a\,a$, are those at which the prism $a\,a$ vanishes, and by drawing the horizontal lines $e\,c$ and f, and joining $m\,t, s\,t, n\,u$, and $r\,u$, the vertical projection of the prisms with their lines of intersection is completed. Here also, as in the other case, fig. 7, the oblique lines at t and u, may be at once drawn by the triangle of 45° from the points m, n, &c.; and thus the complete figures 7 and 9 can be drawn independently of the plan. These figures of themselves, however, will not indicate unequivocally the forms of the prisms, for they may also represent prisms which, while they have the same vertical dimensions, are flatter, or shorter horizontally, in the direction $b'\,d'$.

Penetration of prisms and cylinders at right angles.—$a\,a$, fig. 11, is an elevation of a square prism lying horizontally, penetrated by a vertical cylinder, $b\,f$, of which the diameter is equal to the diagonal of the prism. This is seen in fig. 13, which is a side elevation, in which the square figure $m\,o\,s\,o$ is the end of the prism next it, and the rectangle $d\,b\,f\,g$ is the cylinder, of which the diameter $c\,c$ or $o\,o$ is equal to the diagonal of the prism. Fig 12 is a plan of the figures, which is made by describing the circle $b'\,d'$ representing the end of the cylinder, and drawing two lines through b' and d' parallel to $a'\,a'$, and the terminating lines $a'\,a'$. By carrying up the lines $e'\,e$, $c'\,c$, the vertical projection may be completed, and having found the points m, n, s, r, at which the edges of the prism and the cylinder meet, we are now to find the intersecting lines. Fig. 11 shows that the upper and under parts of the cylinder vanish exactly at the point o where they meet, and a semicircle $m\,o\,n$ being described from the centre t where $m\,n$ and $b\,o$ cut each other, with the radius $t\,o$ and a similar one on the under side, they will represent the intersections of the cylinder and prism.

Figs. 14 and 15 are an elevation and plan of the same prism penetrated by a cylinder of a diameter larger than its diagonal, as will be observed from the plan. By comparing it with the analogous case, figs. 9 and 10, its construction will be at once understood, remarking that, as in fig. 11, the lines of intersection are portions of circles drawn with the radius of the cylinder from the centres t, t, where the vertical centre line cuts the top and bottom of the prism.

Penetration of Cylinders.—Figs. 16 and 17 are the projections of two cylinders at right angles, of which the vertical one is represented by the circle A′ B′ C′ D′ in the plan and by the rect-

Fig. 16.

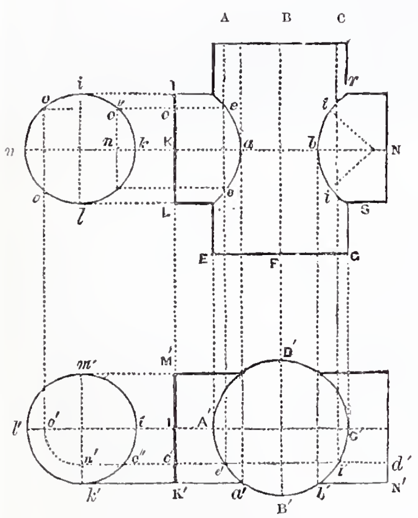


Fig. 17.

Fig. 18.

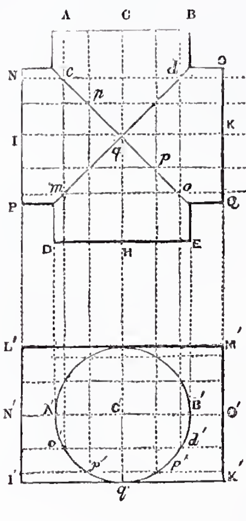


Fig. 19.

Fig. 20.

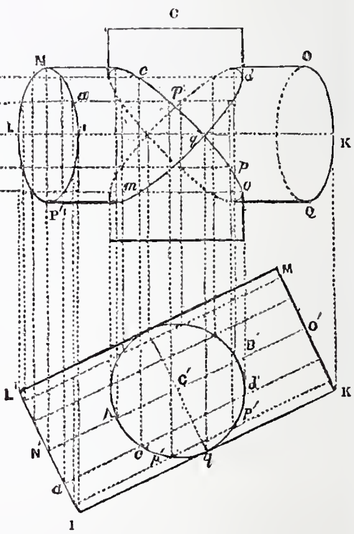


Fig. 21.

angle A C G E in the elevation. The other cylinder, supposed to be horizontal, is represented in both figures by the rectangles I L N and M′ K′ N′. The lines of intersection of the two cylinders as they appear in fig. 16 will be thus determined. It is clear in the first place that the points a' and b' where the line K′ N′ meets the circle are the vanishing points of the cylinder K N, and that they will be found in fig. 16 by carrying up the lines $a'\,a$, $b'\,b$, to the centre line K N. Another line $c'\,d'$ being drawn upon the cylinder M′ K′ N′ parallel to the axis, meeting the circle A′ C′ in e and i', draw perpendicular lines through these points, and let $i\,k\,l\,m$ and $i'\,k'\,l'\,m'$ represent the corresponding ends of the horizontal cylinder. Produce $d'\,c'$ to n' meeting the circle at c'', then c'' is the point c, and taking $k\,n = k'\,n'$, and drawing the perpendicular $n\,c''$, the horizontal line $c''\,c\,e$ is the position in elevation of the line $c''\,c'\,e'$ in plan, and the point of meeting c with the perpendicular from c' is one of the points in the line of intersection. By the same process any other point might be found. A shorter method would be in the first place to draw portions of circles, as $n'\,o'$, from the centre of the circle $i'\,l'$, and through the points n', o', to draw the horizontal $n'e'$ and the vertical $o'\,o$; the lines $e'\,e$, $o\,e$, from these points would as before mark out the intersection. A third method, which is still easier, is simply to draw the semicircle $i\,k\,l$, and to transfer the distance c' K′ to the centre line $k\,m$, giving the point n; through this point having drawn the vertical $n\,c''$ cutting the circle in two points, the horizontal lines, as $c''\,e$, drawn from these points meeting the corresponding verticals, $e'\,e$, &c. give the points in the curve.

We have entered into considerable details on this example, as the methods given for finding the intersecting line are applicable to a variety of other cases. It will be observed that where the diameters of the cylinder are not considerably different, the lines of intersection are at the beginnings $r\,i$, $s\,i$, nearly straight, forming an angle with the horizontal of about 45°. In such instances, having found the point b, a portion of a circle $i\,b\,i$ of which the centre lies in the line K N, may be drawn through this point so as to meet the lines $r\,i$, $s\,i$. This method will save some trouble and will be nearly correct, and the centre of the most proper arc

i b i may be hit upon after a few trials. In cases again where the smaller cylinder is much less than the larger, the line of intersection may be described simply by an arc of a circle passing through the points *r*, *b*, *s*.

To turn to an example of two intersecting cylinders of equal diameters, let figs. 18 and 19 represent two equal cylinders cutting each other at right angles. Then A′ *q*′ B′ represents the upright cylinder in plan, and it will also represent the base of the other cylinder L′ I′ K′ M′, being of the same diameter. Now, dividing this circle into equal parts, say twelve in number, as in the figure,* the points of division will evidently answer for both cylinders; drawing horizontal lines through them for the cylinder N′ O′, and vertical lines for the cylinder A B E D. It is also easy to see that, using the same divisions for the cylinders N P Q O in elevation, the intersections *c*, *p*, *q*, &c. lie in the diagonals drawn through *q*, which are straight lines. Thus the lines of intersection are the same as for equal prisms, fig. 7, and may be drawn in the same way as these, by the triangle of 45°.

Suppose now that the fig. 18 be turned a certain way round on its axis G H, as in fig. 20,† represented also in plan by fig. 21, the projection of the vertical cylinder remains unchanged, while the vertical projection of the other is considerably altered. Its extremities, which are now viewed obliquely, assume the oval form of the curve line termed the *ellipse;* the lines of intersection also appear as ellipses, which are flatter than the others, and we have completed them in broken lines representing the parts which are out of view.

Having drawn the plan, fig. 21, and divided it as in fig. 19, by lines parallel to N′ O′, the axis N′ O′ being at the desired inclination, the vertical projection of any point *c*′, must be in the vertical line *c*′*c*, and also in the horizontal line *c c*, or at their point of intersection *c*, fig. 20. The other points in the line of intersection must be had in the same way as shown in the figure, where it appears that the curves cut one another in two points upon the line L K, of which one, *q*, is visible, corresponding to *q*, fig. 18. Employing the same method for the bases of the horizontal cylinder, we find that the vertical projections of these are the ellipses, shown in the figure.‡

It may be observed that to draw the ellipses in fig. 20, without the aid of fig. 18, it would be necessary to take a vertical line, say N P, and describe a semicircle upon it, which would be divided into the requisite number of parts; from the points of division horizontal lines could then be drawn, cutting the verticals from fig. 21.

Penetration of prisms and spheres.—Figs. 22 and 23 are an elevation and a plan of a sphere or globe intersected by a rectangular prism, and by a cylinder. The prism and the cylinder are both upright, and are represented upon the same vertical axis or centre line C C′, in which line, at the points C, C′, lies also the centre of the given sphere A B. The prism is represented in plan by the rectangle D′ E′ F′ G′, and in elevation by D E I H. Now it is easy to see that when a plane surface meets a sphere, the line of intersection must be the whole or part of the circumference of a circle. In fig. 23, for example, suppose the sphere to be cut downwards through the centre by a plane represented by the line A′ C′ B′, the surface thereby exposed would be a circle of the diameter A′ B′, and represented in elevation by the circle A B. Similarly if we suppose a part of the sphere, fig. 23, to be cut away by another vertical plane *a*′ *b*′, the surface exposed would likewise be a circle of the diameter *a*′ *b*′, and would be represented in elevation by the circle *a* H I *b*, fig. 22, concentric with the circle A B, or drawn from the same centre C. It is obvious then that the intersection of the surface D E I H or D′ E′, which is a portion of the plane *a*′ *b*′, will be represented in elevation by the portion H I of the circumference of the circle *a b*, which is therefore all that is necessary to be drawn.

The cylinder supposed to penetrate the sphere is represented in plan by the dotted circle D′ F′, and in elevation by the rectangle O L M N. It is obvious that while in plan the line of intersection is the circumference itself of the circle, the projection of that line in elevation is the straight line M N perpendicular to the axis.

Figs. 24 and 25, are an elevation and a plan of a sphere intersected by a square prism, C C′ being the axis of the prism, and the points C, C′, the centre of the sphere A B. The prism is represented in plan by the square figure D′ E′ F′ G′; as the sides of it meet the sphere at equal distances from the centre, they will intersect it in equal circles. But it is obvious from the plan that, in the vertical projection, the sides must stand obliquely, and that the lines of intersection must form parts of an ellipse or oblique circle. In fact they are parts of the circle drawn to the diameter *e*′ *f*′, and in the same position. To find any number of points in its elevation, it is obvious in the first place that the middle point *c* of the side is the highest point in the intersection, as it is nearest the centre, and by describing a circle from the centre C′, and with the radius C′ *c*′, till it meet the line A′ B′, and carrying it up vertically till it meet the circle A B, the horizontal lines drawn through these points will indicate the boundaries of the intersection and the vertical *c*′ *c*, which we have shown on the one side, gives the highest and lowest points. Again, bisect E′ *c*′ or F′ *c*′ in either point *o*′, and with the radius O′ *o*′ describe a circle to the line A B, and carry it up till it meet the circle A B; through this point draw a horizontal line, and draw verticals through the points *o*′, *o*′, to meet it; then this gives us other points in the curve. In like manner we may find as many points as may be required. Tracing through these points the curve line D *c* E, we have the line of intersection, which is the same for the other side.

Figs. 26 and 27 are an elevation and a plan of a sphere intersected vertically by a hexagonal prism. The centre of the sphere in its two projections, lies in the axis C′ C of the prism, which is projected horizontally in the regular hexagon, D′ E′ F′ O′ H′ I′. All the lateral faces of the prism, being, as in last example, equally distant from the centre of the sphere, they will meet in parts of equal circles. Now, the vertical face E′ F′ cuts the sphere in a circle, which having *a*′ *b*′ for its diameter, will be represented in elevation by the circle *a* M *b* E on the centre C, with the radius *a*′ C′, the arcs L M and E F being all that is necessary to be drawn.

The intersections of the faces D′ E′ and F′ G′ will be, as in last example, portions of an ellipse, of which the length *d g* is in fact a diameter of the circle we have been describing, and the breadth is the vertical projection *e f* of the diameter in plan *e*′ *f*′. As the parts F *d* O and M *g* N are all that are wanted, we might adopt the following simple mode of constructing them:—

In the first place, it is obvious that the points F and O in the horizontal D O are in the ellipse. Having divided the lines E F and F O into the same number of equal parts, at each point of division of the line E F, erect perpendiculars, meeting the circle E *c* F; then transfer by horizontal lines, their lengths upon the corresponding verticals on F O. The height 1 *h*, for example, will be carried to 1′ *h*′, which will give two points in the arc F *d* O. The arcs M *g* N, D E, and K L, may be traced in the same way.

It will be observed that the construction of the oblique curves in fig. 26 has been more simply effected than in fig. 24, as we have the assistance of the front surface E *c* F for finding the points of the curve.

In drawing fig. 24 again, therefore, it would be more expeditious to draw a temporary circle on the centre C with the radius *c*′ *e*′ or *c*′ *f*′, fig. 25, and to make use of the segment cut off by the line D F, in the same way as in fig. 26.

Penetration of a conical body and a horizontal square prism.—C D, figs. 28 and 29, is the axis of a *truncated cone,** of which the parallel bases are projected horizontally in two circles described upon the centre C; and the horizontals M N and M′ N′ are the axis of the prism of which the base is square, and

* A circle may readily be divided into twelve parts by means of the square and the triangle of 60° and 30°. Thus dividing the circle A′ B′ into four parts by the horizontal and vertical lines A′ B′, C′ *q*′, there remains to divide each of these into three; A′ *q*′, for example. In this purpose, the edge of the square being set parallel to N′ O′, the angle of 30° being set to the point C′, it also marks off the point *c*′, which is one of the divisions; then setting the angle of 60° to the square, and upon the point C, it also marks off the point *p*′. Thus A′ *q*′ is divided in three, and the same process is employed for the other parts; in fact, two opposite parts may be divided at once, or having found the point *c*′, by taking with the compasses the distance A′ *c*′, the divisions will be marked by stepping round the circle from the point A′ or C′.

† In figs. 20 and 21, the cylinder N Q is drawn to a greater length than in fig. 18, for the sake of preventing confusion of lines.

‡ It will be observed that the method of defining the figure of the bases of the cylinder posited obliquely, is exactly the same as that employed for the oblique hexagonal prism, figs. 5 and 6.

* A *truncated cone* simply signifies a cone from which the sharp end is cut off.

of which the faces are respectively parallel and perpendicular to the projections. We have inverted the horizontal projection of these two bodies, in order to expose to view the under side of the cone, and the intersection of the plane F G with the cone; thus the points A′, B′, fig. 29, will be in the same vertical lines as I′ and H′ respectively.

The circle in which the plane F G cuts the cone, is given in fig. 28, by the line F G, and is in the plan partially described upon the

Fig. 22.

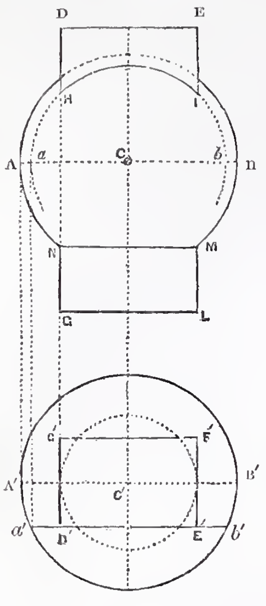


Fig. 23.

Fig. 24.

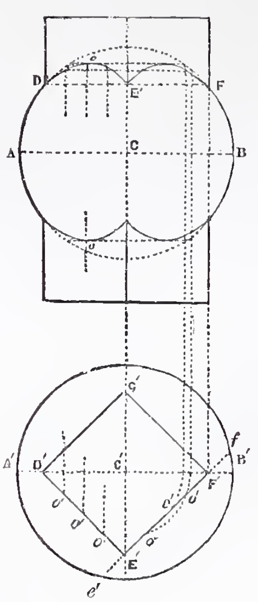


Fig. 25.

Fig. 26.

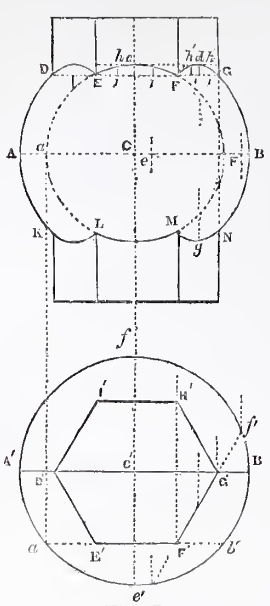


Fig. 27.

Fig. 28.

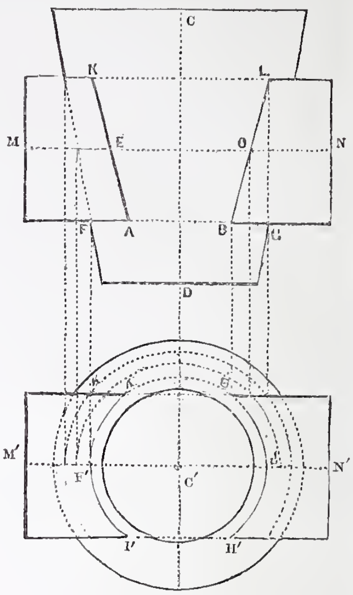


Fig. 29.

centre C′ with the radius of half F G. It is necessary to draw only the portions I′ F′ A′ and H′ G′ B′, to find the intersections K A, and L B of the cone and the prism. It is to be found by means of the perpendiculars B B′, &c., which determine any number of points. In this instance, however, the intersection is so nearly straight, that having found the points B, O, L, it is sufficient to join them by straight lines.*

The subject of the intersection of prisms and spheres is closely

Fig. 30.

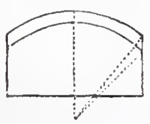


Fig. 31

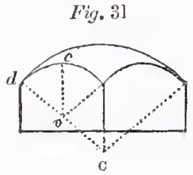


Fig. 32.

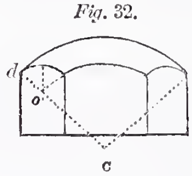
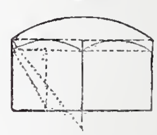


Fig. 33



allied to the customary methods of finishing the ends or bases of prismatic objects. Bolt-heads and nuts, for example, are frequently rounded on the ends in the turning-lathe, into spherical surfaces, from which it appears that whether they be square or hexagonal, they will be drawn in exactly the same manner as the intersections just described. If the oblong prism, fig. 22, were turned on the end, with the same curvature as the sphere A B, it would appear as fig. 30, where there are two curves drawn from the same centre, as indicated in the figure, the one corresponding to H I fig. 22, and the other to the surface of the sphere.

The square prism, fig. 24, being turned on the end, would appear as fig. 31, where it will be noticed the upper contour presents as before, the spherical surface, and the smaller curves the intersections of the sides with that surface, corresponding to D *c* E, fig. 24. Where great accuracy is not desired, a short method of describing the latter curves is by drawing segments of circles from the point *o*, where the perpendicular *o c*, in the middle of the side, meets the line *d* C drawn to the centre.

The hexagonal prism, fig. 26, being turned on the end, will assume the figure 32, where the upper and middle curves, corresponding to the surface of the sphere and the arc E F, fig. 26, are drawn from the same centre C. The smaller curves may be drawn as in fig. 31, upon the centre *o*, where the perpendicular in the middle of the side meets the line *d* C. Fig. 33 is a *side* elevation of fig. 32, being a projection parallel to the plane of C C in fig. 27; the dotted lines there drawn, indicate a ready means of executing the figure.

We might go on indefinitely multiplying examples of the intersections of solids—which of course vary with variety of figure. Those which we have given are among the most ordinary forms of intersections, and include a number of processes which will be applicable to the determination of projections of other geometrical figures.

* The mathematical curve, according to which the cone is intersected by a plane parallel to the axis, is termed a *hyperbola*.

DESCRIPTION OF THE FORTY-FIVE TON CRANE AT GREENOCK HARBOUR.

Made by Messrs. Caird & Company, Greenock.

Description.—Fig. 1 is a side elevation of the crane, in which the arrangement of winding gear is exposed to view by the supposed removal of a portion of one of the cheeks.

Fig. 2 is a plan of the gib, representing the method of joining its two parts at the top.

Fig. 3 is a half-width plan of the base plate.

Fig. 4 is a side elevation of the base plate.

Fig. 5 is a section of the same through the centre.

Fig. 6 is a plan of part of the circular sole upon which the crane turns.

Fig. 7 is a side view of the sole at the centre, L, fig. 6; fig. 8 is a vertical section in the plane, G H; fig. 9 is a section at D E; and fig. 10 is a detached elevation of the joining face of one of the segments of the sole.

Fig. 11 is an elevation of the crane post, also seen in its position in fig. 12.

Fig. 12 is a transverse vertical section of the crane, at right angles to the elevation, fig. 1, and through the central axis of motion.

Fig. 13 is a detached view of the interior surface of the left-hand cheek, fig. 12; giving also a sectional view of the crown or cap; fig. 14 is an edge view of the same; fig. 15 is a sectional view taken in the variable plane, *n n*, fig. 13; figs. 16 and 17 represent the braces which connect the cheeks at the base, and fig. 18 shows the similar braces at the top.

Fig. 19 is an external and a sectional view of the crane barrel.

Figs. 20 and 21 are an elevation and section of one-fourth of the spur-wheel that is keyed upon the barrel.

Figs. 22 and 23 represent a half elevation and a section of the spur-wheel, to which the friction wheel is bolted.

Figs. 24—28 are the shafts of the driving gear of the crane.

Fig. 29 is a segment of the circular rack by which the crane is turned round.

Fig. 30 is a portion of the friction rollers on which the crane turns.

Figs. 31 and 32 are two elevations of the cap of the gib; figs. 33 and 34 are corresponding sections of the same; fig. 35 is a partial elevation and section of the two chain pulleys, the larger of which runs in the cap, and the smaller in the moveable frame of wrought-iron, to which the eye is hung for attaching loads to be raised; fig. 36 is the pin with its washer and cutter, on which the pulley in the cap runs.

Figs. 37, 38, and 39, are sections and plan of the sockets in which the feet of the gib are inserted. This crane is erected on an elevated mass of masonry, which is partially shown in the end view, fig. 12. The masonry is built in courses of 18 inches deep, and the bottom of the foundation is 20 feet below the top of the moveable base plate.

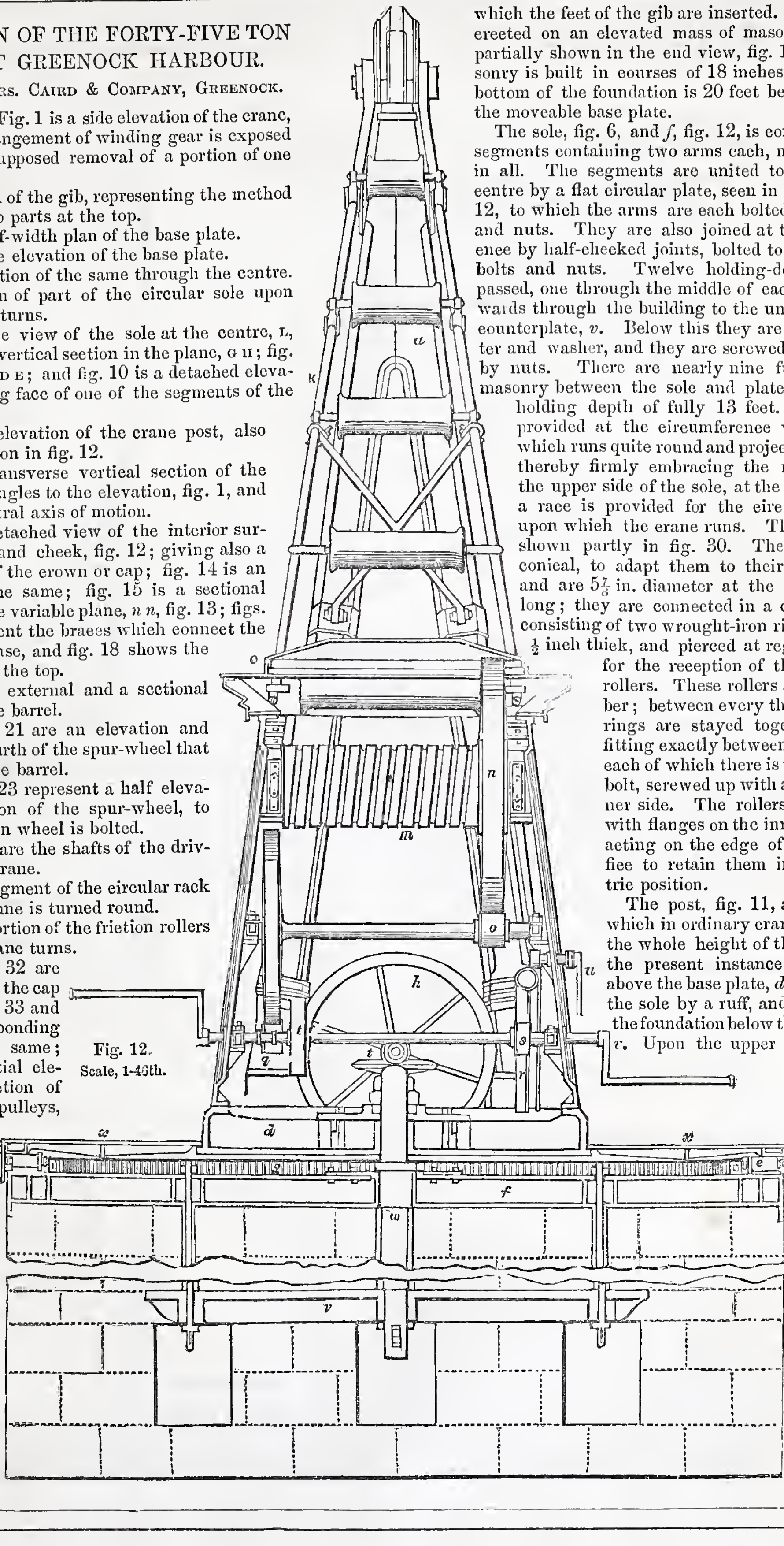


Fig. 12. Scale, 1-46th.

The sole, fig. 6, and *f*, fig. 12, is composed of six segments containing two arms each, making twelve in all. The segments are united together at the centre by a flat circular plate, seen in section in fig. 12, to which the arms are each bolted by four bolts and nuts. They are also joined at the circumference by half-checked joints, bolted together by two bolts and nuts. Twelve holding-down bolts are passed, one through the middle of each arm, downwards through the building to the under side of the counterplate, *v*. Below this they are held by a cutter and washer, and they are screwed up at the top by nuts. There are nearly nine full courses of masonry between the sole and plate, *v*, making a holding depth of fully 13 feet. The sole is provided at the circumference with a flange, which runs quite round and projects downwards, thereby firmly embracing the masonry. On the upper side of the sole, at the circumference, a race is provided for the circulating rollers upon which the crane runs. These rollers are shown partly in fig. 30. They are slightly conical, to adapt them to their circular path, and are $5\frac{7}{8}$ in. diameter at the outside by $12\frac{5}{8}$ long; they are connected in a circular frame, consisting of two wrought-iron rings $2\frac{1}{2}$ deep by $\frac{1}{2}$ inch thick, and pierced at regular intervals for the reception of the axles of the rollers. These rollers are 76 in number; between every three of them the rings are stayed together by tubes fitting exactly between them, through each of which there is passed a $\frac{3}{4}$ inch bolt, screwed up with a nut on the inner side. The rollers are furnished with flanges on the inner side, which, acting on the edge of the race, suffice to retain them in their concentric position.

The post, fig. 11, and *w*, fig. 12, which in ordinary cranes is carried up the whole height of the cheeks, is in the present instance stopped short above the base plate, *d*. It bears upon the sole by a ruff, and is keyed up to the foundation below the counterplate, *v*. Upon the upper end of it, above the ruff, the base plate is accurately fitted, so as to turn freely upon it as a centre. A large circular washer being laid over the plate, a cutter, driven through a groove in the post, enables the latter to resist the tilting action of loads upon the crane. The circular rack, fig. 29, and *g*, fig. 12, is made in segments,

twelve in number, bolted down to the sole, on which the fitting strips for the purpose are seen in fig. 5. The pitch line of the teeth forms a circle of 10 feet $6\frac{1}{2}$ inches radius; the teeth are 5 inches broad, and have 2 inches pitch, and are 396 in number, giving 33 teeth in each segment.

Having described the fixed parts of the crane, we proceed

Fig. 13.

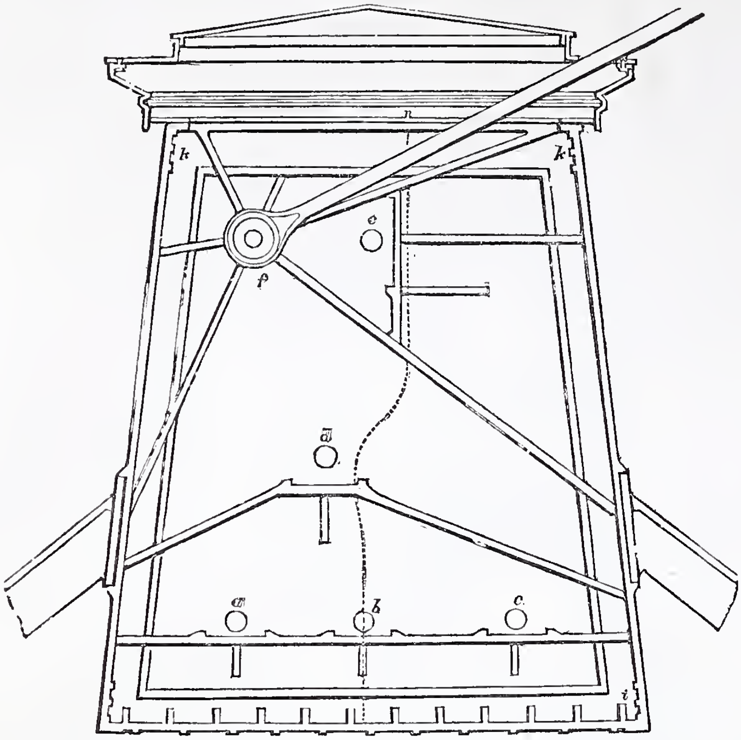


Fig. 14.

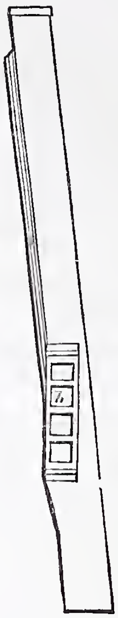
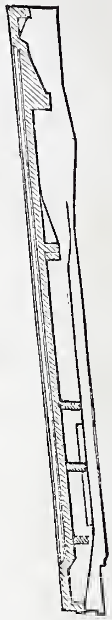


Fig. 15.



to the moveable or revolving portions. In the first place, the base plate is made in two parts, bolted together at the centre, and runs upon the circulating rollers only fore and aft in the direction of the strain, as will be understood both from *d*, fig. 12, and from figs. 3, 4, and 5. The spaces to the right and left of the base plate are covered in by foot plates, *x*, *x*, fig. 12, stiffened by flanges on the under side, and furnished with bearing surfaces to carry them over the rollers.

Fig. 16.

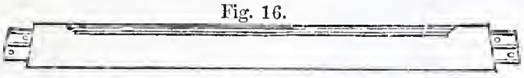
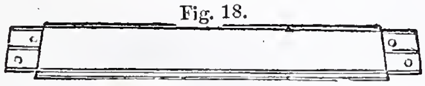


Fig. 17.

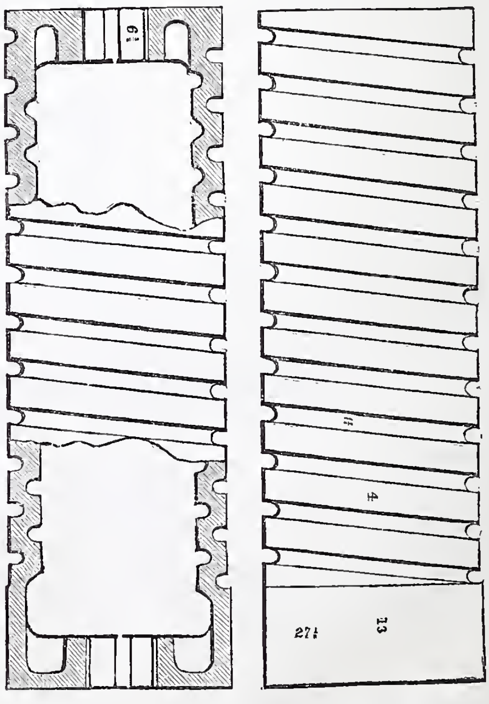
Fig. 18.



Scale for Figs. 13 to 18, 1-48th.

The crane cheeks, fig. 13, are bolted to the base plate, the provisions for which will be seen in fig. 3. Upon the fitting strips at *i*, *i*, *k*, *k*, fig. 13, the braces, figs. 16 and 18, are fitted. These braces steady the checks, and keep the centres of the shafts accurately adjusted. The oblique braces, *h*, *h*, are here partially represented, and the fitting surface of the cheek at *h*, fig. 14. The centres of the shafts are represented at *a*, *b*, *c*, *d*, and *e*; and flanges are raised from the cheeks, to which are bolted the blocks for the bearings of the shafts; these flanges are stiffened also by additional flanges. The stay-rod, *f g*, is fixed to the cheek at *f*, being formed with an eye four inches deep, which is received upon a boss $9\frac{7}{8}$ inches diameter, cast upon the cheek, and stiffened by numerous flanges. The stay-rods are $3\frac{3}{4}$ inches diameter throughout, and are 50 feet 3 inches

Fig. 19.—Scale, 1-24th.



long between centres. A square-headed bolt, countersunk on the outside of the cheek, passes through the boss, and receives

a washer which secures the eye of the tie-rod, and which is itself secured by a screw nut.

The centre of the barrel shaft, *e*, fig. 13, corresponds to K, fig. 1. The shaft itself, fig. 24, is $6\frac{3}{8}$ inches in diameter; at

Fig. 20.

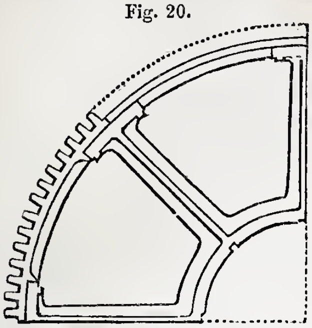


Fig. 21.

Fig. 22.

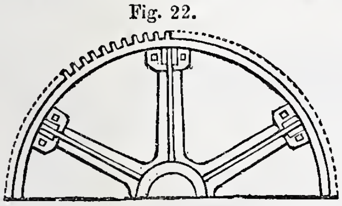


Fig. 23.

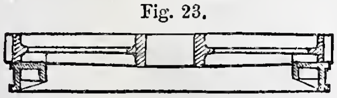
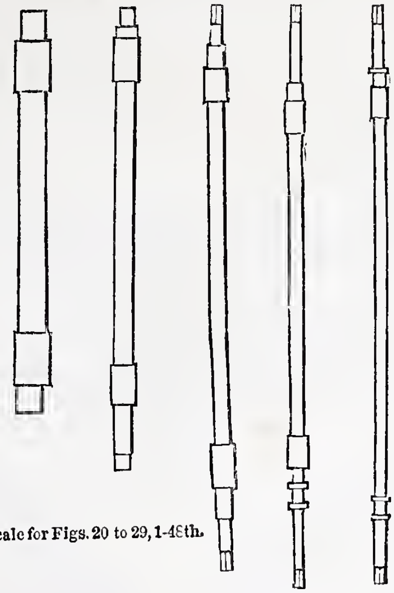


Fig. 24. Fig. 25. Fig. 26. Fig. 27. Fig. 28.



Scale for Figs. 20 to 29, 1-48th.

Fig. 29.

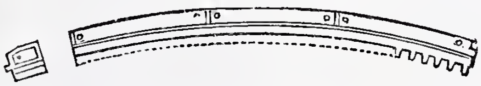
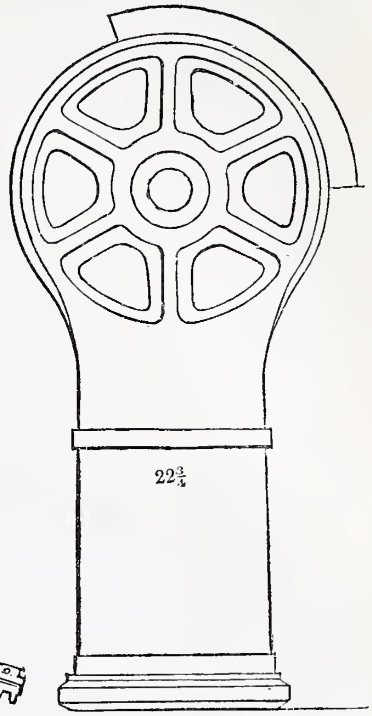


Fig. 31.—Scale, 1-24th.



the bearings for the barrel, 8 inches; and at the journals, $5\frac{5}{8}$. The barrel, fig. 19, and *m*, fig. 11, is 7 feet long by $27\frac{1}{8}$ inches diameter. Its circumference is indented with a spiral groove for the reception of the chain, making twelve turns. The

Fig. 32.

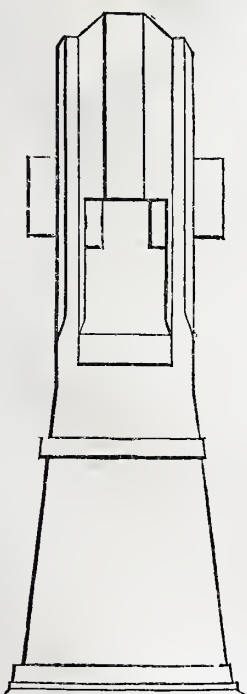


Fig. 33.

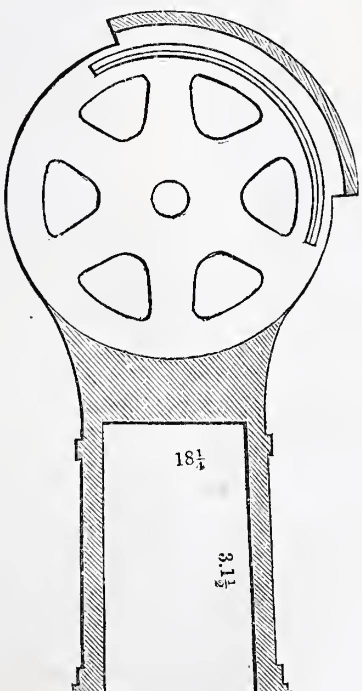
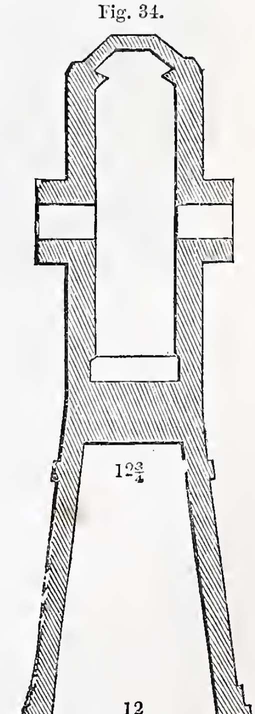


Fig. 34.

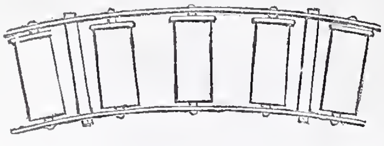


Scale for Figs. 32 to 34, 1-24th.

barrel wheel, figs. 20, 21, and *n*, fig. 12, is keyed upon the plain part on the outside of the barrel. The arms, eight in number, are cast in one piece with the boss; the ring is cast separately, in eight segments, which

are bolted to the arms. The wheel is 98 inches diameter; it has 112 teeth of $2\frac{3}{4}$ inches pitch, and 8 inches broad. This wheel gears into a pinion, *o*, fig. 12, upon the second shaft, *d*, fig. 13, seen also in fig. 1. This pinion is $12\frac{1}{4}$ inches diameter, and has

Fig. 30.



14 teeth of $2\frac{3}{4}$ inches pitch, and $8\frac{1}{2}$ inches broad. The shaft, fig. 25, is $4\frac{3}{4}$ inches diameter; in the wheel and pinion, $5\frac{1}{2}$ inches diameter, and at the journals $3\frac{5}{8}$. The wheel upon this shaft,

Fig. 35.

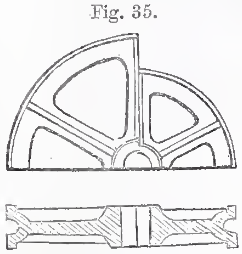
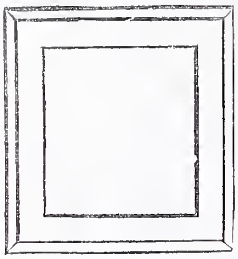


Fig. 36.

Fig. 37.



p, fig. 12, is $75\frac{1}{2}$ inches diameter; and the teeth, 107 in number, are $2\frac{1}{4}$ pitch by $5\frac{1}{2}$ broad. It gears into pinions, *t* and *q*, upon the shafts, *a* and *b*, fig. 13, and figs. 26, 27. The pinion, *t*, on the shaft, *a*, is $21\frac{1}{4}$ inches diameter; it has 30 teeth, $5\frac{3}{4}$ inches

Fig. 38.

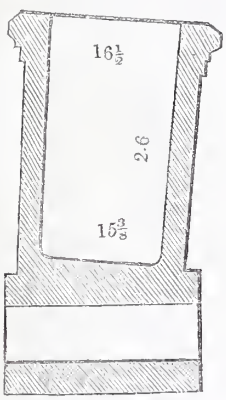
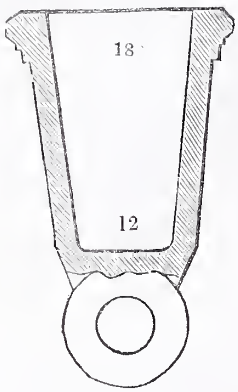


Fig. 39.



Scale for Figs. 30 to 39, 1-24th.

broad. The shaft, *a*, carries another pinion, *s*, at the other end, 10 inches diameter, having 18 teeth, $1\frac{3}{4}$ pitch, and 4 inches broad. The shaft itself is 3 inches diameter. The pinion on the shaft, *b*, which gears into the wheel on the shaft, *d*, is $10\frac{1}{2}$ inches diameter; it has 15 teeth. On the other end of this shaft is fixed a spur-wheel, fig. 22, which gears into the 10 inch pinion on the shaft, *a*. That wheel is $53\frac{1}{2}$ inches diameter, and has 97 teeth of $1\frac{3}{4}$ pitch. Finally, the pinion on the shaft, *c*, which gears into this wheel, is $21\frac{1}{2}$ inches diameter; it has 38 teeth. The shafts, *b* and *c*, are respectively $3\frac{5}{8}$ and $2\frac{3}{4}$ inches diameter. The friction-wheel is bolted to the side of the wheel, fig. 22, on the shaft, *b*, as shown in the section, fig. 23, and in fig. 12, in which last figure is also shown the lever, *u*, for working the strap. The shaft, *a*, has a double shift lengthwise, which allows of a variety of different speeds being attained; the driving-handle may be applied to any of the three shafts, *a*, *b*, *c*.

A pinion, $7\frac{5}{8}$ diameter, with 12 teeth, works into the fixed rack. It is driven by the wheel, *h*, fig. 12, from which the motion is communicated to it by means of the bevel wheel and pinion, *t*, which are respectively 32 and 9 inches diameter. By this means the crane may be turned about on its centre.

THE SCIENCE OF PHRENOLOGY.

CHAPTER IV.

ORDER I.—FEELINGS.

Genus I.—Inferior Propensities.

This class of feelings may be said to be common to man and the inferior animals; they are not used to procure knowledge, or to generate ideas, their functions may be said to be adequately expressed under the term propensity.

1. Amativeness.—The cerebellum (see fig. 5, &c.) is the organ of this propensity: its proofs may be sought in Dr. Gall's work on the Functions of the Brain, Vol. III. p. 141 to 239. It has been ascertained that this propensity is manifested by means, as just stated, of the cerebellum. In this portrait of Caracalla it is largely developed: but the relative size will perhaps be better estimated by a comparison of the two following cuts.

In figure 1, its situation is marked by the No. 1, and in this representation the organ is small; but in figure 2, which gives the same view of another skull, it is seen in much larger pro-

CARACALLA.

portion. In Dr. Gall's large work, the portion which treats of the cerebellum, extending to 98 pages, is left untranslated, probably from delicacy to the non-professional reader; but it is impossible to unite a greater number of proofs in demonstration of any natural truth, than may be presented to determine the functions of this organ. It may be denominated the instinct of reproduction: its functions give rise to the passion of love. Its abuse is lewdness and libertinism.

"Some men of science pretend that it is impossible to judge of the size of the cerebellum during life in the human species, because," say they, "from the projection which is felt, almost immediately above the hollow of the neck, to the occipital hole, it is impossible to feel the skull. But it is precisely in this place that the two lobes of the cerebellum separate, and leave between them a space in which the lower portion of the vertical part of the occipital spine is placed, in consequence of which the form of the cerebellum is not concealed. About half an inch toward the side, the posterior and inferior portion of the occipital bone forms an arch towards the posterior edge of the mastoid bone. The more this prominence is arched, the more it descends towards the nape of the neck; the more it enlarges itself towards the ears, the greater is the size of the cerebellum. In this case, the nape of the neck is large and thick, the neck rounded, and large and thick behind the ears.

When, on the contrary, the cerebellum is little developed, these parts are flat, narrow, and depressed. The neck, although thick where it leaves the trunk of the body, will be narrow between one mastoid process and the other."*

In children, the cerebellum is smaller than in adults, and in women and females generally it is less than in men and males. It generally attains its full growth between sixteen to twenty-five years of age, and frequently diminishes in old age. In some adults it is exceedingly small, in others moderate, and in others again very large. Sometimes it is of great magnitude in children, and then its special function, the propensity we treat of, appears in early life.

The situation of the organ is between the mastoid process behind the ear, and the occipital spine in the middle of the lower and back part of the skull. The space between these two elevations indicates the extent of the organ in man; and its general size, viewed in relation to the other organs, may be compared with the energy of its primitive function in each individual of the human species.

The influence of this feeling upon society is immense, and perhaps there is no organ that requires a greater degree of care and watchfulness. Who that has witnessed the horrors attendant on seduction, or read of its consequences and generally fatal termination, but that must regard the regulation of the sexual feelings and functions as of the deepest consequence. Legislators, moralists, teachers, ministers of the gospel, physicians, and, in short, all who value the peace of society, and the happiness of the beings who compose it, are concerned in regulating the sexual propensity.

Dr. Spurzheim has earnestly exhorted parents on the necessity of instructing young persons in the consequences of its improper indulgence; and this they may most effectually enter upon, by making phrenology a family study. We shall, in the remarks which follow, blend the ethics of phrenology with its scientific details.

The social affections, Amativeness, Philoprogenitiveness, Inhabitiveness, and Adhesiveness, which we shall treat of in this chapter, are often dignified by the name of household virtues: such they really are, when properly guided by those higher feelings, and by the intellect which the Creator has bestowed upon us. They comprehend the duties of married partners towards each other, to their children, and to the community of which they are members. These duties do not occupy the attention of the public so much as their importance deserves, and the aim of the phrenologist is to call the attention of parents to them, so as to direct their functions into their proper and legitimate channel. The neglect of duty on the part of parents in not properly training and educating their children, is the cause of most of the miseries which married partners endure. It is impossible to speak in terms too impassioned, of the wisdom with which the Supreme has adapted the sexes to each other—an adaptation, in which wisdom joins with affection, strength with weakness, firmness with feeling, and dignity with beauty. There is, indeed, an admirable partition of qualities between the sexes, which the great Author of our being has distributed to each with a wisdom which calls for our admiration. Man is strong, woman is beautiful. Man is daring and confident, woman is diffident and unassuming. Man shines abroad, woman at home. Man talks to convince, woman to persuade and please. Man has a rugged heart, woman a soft and tender one. Man is a being of science, woman of taste. Man has judgment, woman sensibility. Man is rather a being of justice, woman of mercy. Indeed, each principle and quality in the one sex is formed to unite with its similar, and yet in some sense contradictory, correlative in the other. And it is this circumstance that causes everything proceeding from the one sex to appear to the other as unceasingly imbued with, and adorned by, the graces and freshness of the other. And inasmuch as the relation between the sexes is thus a compendium of all the relations that can exist between human beings, whether scientific, intellectual, moral, spiritual, and eternal, together with additional uses peculiar to marriage; it thence results that the all-bounteous Creator has collated into marriage all the happiness attainable by rational creatures. If these remarks be admitted as true, and if to them be added the advice of a high authority, "*be not unequally yoked,*" then surely the very threshold of our subject seems to present us with matter for the gravest reflection; and if phrenology presents parents with the means of so training their children that unhappy and ill-assorted unions may be prevented, then to neglect applying its principles, is to render themselves doubly culpable.

Fig. 15.

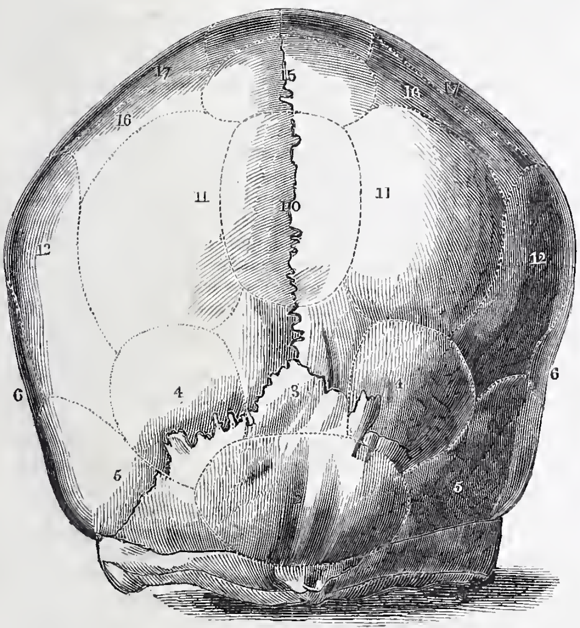


Fig. 16.

"It is well known that no method of discovering, with reasonable success, the natural dispositions of human beings has

* Combe's Translation, p. 15. Gall on the Functions of the Brain, Vol. III. p. 157, 158. Boston edition, 1835.

hitherto existed. The general intercourse of society, such as is permitted to young persons of different sexes before marriage, reveals, in the most imperfect manner, the real character; and hence the bitter mortification and lasting misery in which some prudent and anxious persons find themselves involved, when the blandishments of a first love have passed away, and when the inherent qualities of the minds of their partners begin to display themselves without restraint. The very fact, that human affection continues in this most unhappy and unsuccessful condition, ought to lead us to the inference, that there is some great principle relative to our mental condition undiscovered, in which a remedy for these evils will be found. The fact that man is a rational creature, who must open up his own way to happiness by means of knowledge, ought to lead us, when misery is found to result from our conduct, to infer, that we have been ignorant or reckless, and that we ought to seek new light, and to take greater care in future. Far from its being incredible, therefore, that a method has been provided by the Creator whereby the mental qualities of human beings may be discovered, this supposition appears to be directly warranted by every fact which we perceive and experience connected with his government of the world. If God has placed within our reach the means of avoiding unhappy marriages, and if we neglect to avail ourselves of this gift, then are we ourselves to blame for the evils we endure. I cannot too frequently remind you, that every fact, physical and moral, with which we are acquainted, tends to show that man is comparatively a recent inhabitant of this globe; that, as a race, he is yet in his infancy, and that you ought no more to be astonished at new and valuable natural institutions, calculated to promote human enjoyment and virtue, evolving themselves from day to day to our understandings, than you are at the obviously increasing intelligence of an individual as he passes from childhood to youth, and from youth to manhood."*

If we turn our attention to many of the marriages of the present day, we might be led to infer, that instead of the union being a solemn and important contract, one involving happiness or misery, it was a mere agreement for temporary convenience, as well as for the necessary propagation of the species. How many young persons of both sexes are there, who have scarcely another idea of marriage than those just stated! Tell them they ought to be well assured of their suitability for each other, both morally and physically—that the contract is a most onerous engagement, and they smile at your primitive notions. But in how many thousand instances is i. verified, that after a short period of married life, sensual indulgence was all they sought for; in every other sense of the word, they have proved their ignorance of, and unsuitability for, each other! It would have been otherwise had the moral and spiritual, as well as the physical laws been obeyed.

"Upwards of ten years ago,"† says Mr. Combe, "I had a short interview with an individual who was about to be married to a lady with whom I was acquainted. In writing this piece of news to a friend at a distance, I described the gentleman's development of brain, and expressed my regret that the lady had not made a more fortunate choice. My opinion was at variance with the estimate of the lover made by the lady's friends from their own knowledge of him. He was respectably connected, reputed rich, and regarded as altogether a desirable match. The marriage took place. Time wheeled on in its ceaseless course, and, at the end of about seven years, circumstances occurred of the most painful nature, which recalled my letter to the memory of the gentleman to whom it had been written. He had preserved it, and after comparing it with the subsequent occurrences, he told me that the description of the natural disposition coincided so perfectly with those which the events had developed, that it might have been supposed to have been written after they had happened."

It can easily be proved, that, among the wealthy, many marriages originate in covetousness; the suitability as to physical conformation, temper, and disposition is rarely, if ever, consulted. A woman is often married, not merely at the suggestion, but at the command of her parents, in order that estates belonging to different branches of the same family may be united in one. And even among the poor, there is too often a greater looking to dowries than to suitability of disposition and temper,‡ and station in life.

There is no greater evil in the sequel than marriages between blood relations. In Scotland, and indeed in some parts of England, the practice of full cousins marrying is not uncommon, and the results may be seen in the debilitated frames, or in the rapid deaths of the offspring or of the parents.

In *Galignani's Messenger* of 1846 was the following paragraph:—"The deaths of the Count and Countess de Noailles were attended by extraordinary and interesting circumstances. They were *cousins*, and both previous to their marriage bore the same name. Being brought up together, they became attached to each other from their infancy, but as the constitution of each was so feeble as to indicate premature death, their parents long opposed their union. At last, however, from their own earnest entreaties, their marriage was consented to and solemnized. Their maladies rapidly increased. The countess could not bear the slightest degree of cold. Her physicians ordered that her apartments should always be kept at a certain height of temperature. The count, on the contrary, required to be in a fresh and cool atmosphere. They consequently seemed to be doomed to constant separation even in this life. That, however, they might at least see each other, they were placed in rooms adjoining, the partition between which was plate glass, through which they were able to communicate, but by looks and signs alone. Not more than one year elapsed between their wedding and their funeral."

The children of healthy cousins are not so favourably organized, as the children of the same parents, if married to equally healthy partners not at all related in blood, would have been.

Another law relating to marriage is, that the parties should possess sound constitutions. The punishment for neglecting this law is, that the transgressors suffer pain and misery in their own persons from bad health; perhaps become disagreeable companions to each other, feel themselves unfit to discharge the duties of their condition, and transmit feeble constitutions to their children. They are also exposed to premature death; and hence their children are liable to all the melancholy consequences of being left unprotected and unguided by parental affection and experience, at a time when these are most needed. The natural law is, that a weak and imperfectly organized frame transmits one of a similar description to offspring, and the children inheriting weakness are prone to fall into disease, and die. Indeed, the transmission of various diseases founded on physical imperfections from parents to children, is a matter of universal notoriety: thus, consumption, gout, scrofula, hydrocephalus, rheumatism, and insanity, are well known to descend from generation to generation. Strictly speaking, it is not disease that is transmitted, but organs of such imperfect structure that they are unable to perform their functions properly, and so weak that they are easily put into a morbid condition by causes which sound organs could easily resist.

Another violation of the natural laws is, marriages contracted at too early an age—before the physical constitution of either of the parties is sufficiently developed, and certainly, as already hinted, before the parties are sufficiently acquainted with the deep responsibilities consequent upon the union.§

We recommend to the attentive consideration of the reader, Mr. Combe's "Moral Philosophy," where the subject of marriage is treated of both scientifically and philosophically; and to this advice we would add the study of the subject upon moral and spiritual grounds—that is, viewed from the moral and religious sentiments.

* Combe's Moral Philosophy.
† Moral Philosophy. Edit. of 1841, consequently now 22 years ago.

‡ The Rev. Gilbert White used to say to neighbour Barboy—"Never marry for a fortune. There is Dame ——— scolding her husband, as I passed the cottage, because she brought him a dowry.—'You good-for-nothing fellow,' she said, 'what would you have been had I not married you? whose was the baking kiver, whose the pig trough, whose the frying-pan and iron-hooped bucket; whose, but mine, when you married me, you good-for-nothing fellow!' O neighbour! neighbour! repeated the old naturalist, "never marry for wealth."
§ Moral Philosophy—Combe.

"Nothing hinders the constant agreement of people who live together, but selfishness or mere vanity; a secret insisting upon what they think their dignity and merit; an inward expectation of such an over-measure of deference and regard as answers their own extravagant false scale, and which nobody can pay, because none can tell readily to what pitch it amounts to."* Thousands of married people would be happy to-morrow if they would but remember this, and if they would have the courage to apply it to themselves; and this they would, if they were to study first their own organization, and, secondly, those of the partners to whom they are united. When the duties of husband and wife, respectively, are performed under the principle of affection, guided by benevolence, adhesiveness, and justice, the married state will be found as perfect a state of happiness as can be found on earth.

I will only add, that the statistics of matrimony prove that it is favourable to longevity. It has been computed, that at the age of 60, there are but 22 unmarried men alive for 58 married; at 70, 11 bachelors for 28 married; and at 80, there are for every three bachelors, nine married men. Very nearly the same proportion holds good in the female sex; of whom, while 72 who have married attain the age of 45, only 52 unmarried reach the same term of life. Perhaps one great cause of this difference is the circumstance of that tenderness of friendship, which we will hope does in most cases exist between those who are yoked together for life.

MARRIAGE.

"Purest, sweetest, earliest flower,
Born to brighten Eden's bower,
Sole relationship that dwelt
There where sin was yet unfelt;
Still amid this wearied earth
Thou hast traces of thy birth;
Parent stem, whence rose and rise
All our countless kindred ties;
Sad and savage life would be
'Reft of tenderness and thee.

"Child of heaven, the sordid soul
Cannot know thy pure control;
Thy ethereal union binds
None but high and hallow'd minds;
Hearts instinct with love divine
Sweetly blend before thy shrine,
Blend their confluent rills that meet
Mid some valley's calm retreat,
Mingling pure as morning's beam,
Twain in fountain, one in stream;
Theirs no glow that fades away—
Loving once, they love for aye."

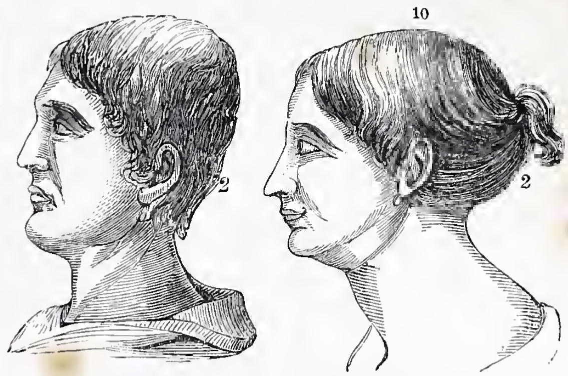
* * * * * * *

"Call'st thou that marriage which but joins
Two hands with iron bonds? that *yokes*, but not
Unites, two hearts whose pulses never beat
In unison? The legal crime that mocks
The very name of marriage—that invades,
Profanes, destroys its inner holiness?
No! 'tis the spirit that alone can wed,
When with spontaneous joy it seeks and finds,
And with its kindred spirit blends itself!
My liege, there is no other marriage tie!"

2. Philoprogenitiveness.—Nature, says Dr. Gall, by another organ, secures the existence and prosperity of beings procreated in consequence of the instinct of propagation. In all animated nature there is manifest an imperious propensity to preserve and cherish offspring. We admire it in the insect, and it commands our respect even in the tigress.

How happens it, that neither philosophers nor physiologists have made any serious researches in relation to this propensity? No one has endeavoured to discover the origin of this preserving instinct. No one has examined why this propensity differs in manifestation in different species, in the two sexes, and in different individuals. Does it result from the organization, taken collectively, or does it depend on an isolated part? These are questions, which, prior to the time of Dr. Gall, were never asked. He gives the history of the discovery of the love of offspring as a fundamental quality, and of its origin in the following language.

On comparing, with indefatigable perseverance, various forms of head, Dr. Gall observed that, in most of the heads of females, the superior part of the occipital bone recedes more than in the heads and crania of men. [Compare the female portrait below at the mark 2, with the opposite cut at the same situation, and the difference is most striking.]



Philoprogenitiveness moderate. Self-Esteem large.

Philoprogenitiveness large. Self-Esteem moderate.

As this prominence of the occipital bone is evidently produced by the brain, it follows that the subjacent cerebral part is, in most instances, more developed in woman than in man. What was, then, more natural than the idea, that this cerebral part might be the material cause of a faculty or quality manifesting itself in a greater degree in woman than in man? But then the question arose, what was that faculty or quality? In examining and comparing the skulls in his numerous collection, he at length discovered, that in the crania of female animals distinguished for attachment to their young, the back of the head towards the occipital bone always presented an enlarged appearance; this he found to be uniform, although in other respects they were very differently formed. He next observed the crania of females of the human species, and the same configuration presented itself. After this, he commenced a round of careful observations on the living. He visited schools, carefully observing and discriminating the form of head in the female children, and in the governesses who had the superintendence of them; and though the configuration of the part we are describing varied in size—being in some very elevated, and in others but moderately so—yet, in all, it presented a difference to the configuration at the same spot in men and boys. Wherever any person was distinguished for love of children, he strove to gain a sight of their heads; and at length, after a multitude of facts, he set down the organ as established, and described its functions as the love of offspring. Assisted by Benevolence, and under the control of Firmness and Cautiousness, this affection is one of the noblest in the female character. It is this organ which prompted the sentiment of the Roman mother, who, when presenting her children, exclaimed, "*These are my jewels.*" Every woman, indeed, delights in her own offspring, and considers it the most perfect. "It is," says the author of *Woman's Records*, "a happy instinct which enables us to value these little pledges so highly, and a curious thing to reflect, that as we stumble through the parks, knee-deep in children, there is not one little unit in these diminutive millions, that has not (God bless it) a circle of admiring relatives, to whom it is the prettiest, the dearest, the cleverest—in fact, the only child that ever was worth a thought."† In illustration of the high esteem in which a mother holds her child, of the affection and admiration with which she regards it, and, consequently, of the power and fervour of the feeling under consideration, I cannot do better than transcribe from a Glasgow poet—

* Pope.

† To the same purpose, the "Englishwoman in Egypt" (vol. i., p. 68) writes—"Contend against me who may, I must ever maintain my opinion, that no love is so deep, no attachment so strong, as that of mother to child, and of child to mother."

THE WONNERFU' WEAN.

Our wean's the most wonnerfu' wean e'er I saw—
It wad tak me a lang summer day to tell a'
His pranks frae the morning till night shuts his e'e,
When he sleeps like a peerie 'tween faither an' me.
For in his quait turns siccan questions he'll spier,
How the mune can stick up in the sky that's sae clear?
What gars the wun blaw, an' whaur frae comes the rain?—
He's a perfect divert—he's a wonnerfu' wean.

Or wha was the first bodie's faither? an' wha
Made the vera first snaw-show'r that ever did fa'?
An' wha made the first bird that sang on a tree?
An' the water that sooms a' the ships on the sea?
But after I've tell't him as weel as I ken,
Again he begins wi' his wha'? an' his when?
An' he looks aye so watchfu' the while I explain—
He's as auld as the hills—he's an auld-farrant wean.

An' folk wha hae skill o' the lumps on the head,
Hint there's mair ways than toiling o' winnin' ane's bread—
How he'll be a rich man, an' hae men to work for him,
Wi' a kyte like a bailie's, shug, shuggin' afore him—
Wi' a face like the mune, sober, sonsy, and douse,
An' a back for its breadth like the side o' a house;
'Tweel I'm unco tae'n up wi't, they mak' a' sae plain—
He's just a town's talk—Oh, a by-ord'nar wean!

I ne'er can forget sic a leuch as I gat
To see him put on faither's waiscoat an' hat,
An' the lang-legglt boots gaed sae far ower his knees,
The tap loops wi' his fingers he gripped wi' ease.
Then he marched through the house—he marched but—he marched ben,
So like mony mair o' our great little men,
That I leuch clean outright, for I couldna contain,
He was sic a conceit—sic an ancient-like wean.

But mid a' his daffin', sic kindness he shows,
That he's dear to my heart as the dew to the rose,
An' the unclouded hinnie-beam aye in his ee
Mak's him every day dearer an' dearer to me.
Though fortune be saucy, an' dorty, an' dour,
An' glooms through her fingers like hills through a shower,
When a body has got ae bit bairn o' their ain,
He can cheer up their hearts—he's the wonnerfu' wean.

THOMAS MILLER.

But if this affectionate principle be the source of so much happiness when controlled by Firmness and Cautiousness, and under the guidance of the intellect, it is calculated to be destructive of the little being's future happiness if improperly exercised. The parent has no right to blame nature, but rather to blame her own negligence and bad customs. "It is," says Jeremy Taylor, "the neglect of a field which causes fern and thistles to grow. It is not because the ground is accursed, but because it is neglected, that it bears thorns."

When very largely developed, this faculty sometimes induces insanity. Dr. Andrew Combe mentions the following instance:—"While the fit lasted, which was for three days, her constant exclamation was for her children; sometimes she imagined them carried away and murdered, at other times they were suffering great distress, and exposed to unheard-of calamities. On her recovery, she complained of the greatest pain in the back part of her head. She knew nothing of phrenology. But she described the seat of pain as exactly residing in the cerebral part, where Philoprogenitiveness develops itself."

There is a class of ladies, both unmarried and married, the latter without children, who indulge a fondness for animals of the small and delicate kind. This results, in all probability, from an enlarged development of the faculty, which, failing gratification in the natural way, turns its attention to the animals alluded to. These ladies are frequently made the subject of ridicule, but they rather deserve our forbearance and respect. They are merely following the bent of a strong natural propensity, implanted in them for the wisest of purposes, and which, in more favourable circumstances, would have rendered them affectionate mothers and excellent mistresses of families.*

Deficient as many of the savage tribes are in Benevolence, they yet have this propensity fully developed. In the savage tribe of the Charibs, the organ is decidedly marked. Of five casts in the Phrenological Society's Collection, one has the organ very large, three large, and one rather full. Whenever the faculty is not developed in woman in very fair proportion, it leads to carelessness of offspring, sometimes to infanticide In proof of this, Dr. Gall relates the following facts:—

"I knew, at Vienna, a lady who loved her husband tenderly, who managed the affairs of her household with intelligent activity, but who sent from home, immediately after their birth, all the nine children of which she was successively delivered, and for years she never desired to see them. She was herself astonished at this indifference, and could not account for it. In order to acquit her conscience, she required that her husband should daily see her children, and attend to their education."†

"Of twenty-nine women who had committed infanticide, that we (Gall and Spurzheim) had occasion to examine, the organ of the love of offspring was very feebly developed in twenty-five."‡

3. INHABITIVENESS, CONCENTRATIVENESS.—The organ of Inhabitiveness is placed above that of Philoprogenitiveness, at the upper end of the occipital bone. On this organ, Dr. Spurzheim remarks:—

"In examining the manners of living of different animals, it is obvious that particular kinds are attached to different and determinate localities, regions, and countries. Some seek the water from the moment of their existence; the turtle and duck, as soon as they are hatched, run towards it. Certain species, as the chamois, wild goat, ptarmagan, &c., select elevated regions for their haunts; others prefer low countries and plains. Among the inhabitants of the air, some species hover principally in the upper regions; others, although their power of flying is great, live in lower strata, or on the banks of rivers. Some birds build their nests on the tops of trees, others at the middle branches, others again in the holes of their trunks, or on the earth.

"In conformity with all these considerations, I admit a primitive faculty and special organ which determines animals in their dwellings. This power, however, is modified in different animals. It varies in land and in water animals, just as the senses of smell and taste vary in herbivorous and carnivorous animals."§

"My attention has been directed to such individuals of the human kind, as show a particular disposition in regard to their dwelling-place. I have many facts in confirmation. I saw a clergyman in Manchester, known to his friends as particularly attached to his dwelling-place, so that he should be unhappy if obliged to sleep elsewhere. I examined his head in company of several gentlemen, some of whom were opponents, but every one was obliged to admit, that the spot of the head where No. 3 is situated was warmer than the rest of the head. I merely asked what part was the warmest, and all agreed at the same place. Some nations are extremely attached to their country, while others are readily induced to migrate. Some tribes of the American Indians and Tartars wander about without fixed habitations, while other savages have a settled home. Mountaineers are commonly much attached to their native soil, and those of them who visit capitals, or foreign countries, seem chiefly led by the hope of getting money enough to return home and buy a little property, even although the land should be dearer there than elsewhere."‖

The situation of this faculty—closely as it is in connection with Amativeness, Philoprogenitiveness, and Adhesiveness—is to us a proof that it is a purely affectionate feeling, and does not at all take cognizance of the intellect, although its connection with the intellectual faculties, like the other subjective feelings, is close and intimate. It appears that the real effect of this organ is to render a person mechanical in his habits and actions, to go through the same invariable routine. It will thus create a dislike of change of place and action, and so beget a love of staying at home, where the organ can be best gratified by its usual occupations.

* Phrenological Journal, Vol. II., p. 499, 500.

† Gall's Works, Vol. III., p. 282, Boston edit.
‡ Gall's Works, Vol. III., p. 283, Boston edit. We may here, once for all, state, that all our quotations from Gall and Spurzheim's works are from American editions.
§ Spurzheim's Outlines.
‖ Spurzheim's System, 1832, p. 167.

But the love of home is but an individual part of the use of this organ. It extends its influence to the love of country, which may be considered as a man's home in a more extended sense of the word. Mrs. Opie, in her tale of the "Welcome Home," makes Ronald Breadalbane thus apostrophize Scotland:—"O Scotland! dear Scotland! land of the mountain and the vale! land of beautiful women and of brave men! land of genius and of song! land of kindness and hospitality! I bring to thee an unchanged heart, my country, and a conviction that there is nought like thee upon the habitable globe."

Sir Walter Scott, in Canto VI. of the "Lay of the Last Minstrel," has these thrilling stanzas on home:—

"Breathes there a man with soul so dead,
Who never to himself hath said,
This is my own, my native land!
Whose heart hath ne'er within him burn'd,
As home his footsteps he hath turned,
From wandering on a foreign strand!
If such there breathe, go, mark him well;
For him no minstrel raptures swell;
High though his titles, proud his name,
Boundless his wealth as wish can claim;
Despite those titles, power, and pelf,
The wretch, concentred all in self,
Living, shall forfeit fair renown,
And, doubly dying, shall go down
To the vile dust, from whence he sprung,
Unwept, unhonoured, and unsung.

"O Caledonia! stern and wild,
Meet nurse for a poetic child!
Land of brown heath and shaggy wood,
Land of the mountain and the flood,
Land of my sires! what mortal hand
Can e'er untie the filial band,
That knits me to thy rugged strand!
Still, as I view each well-known scene,
Think what is now, and what hath been,
Seems as, to me, of all bereft,
Sole friends thy woods and streams were left;
And thus I love them better still,
Even in extremity of ill."

While Scotland has thus eloquently been described, England has found no less powerful a writer in the person of the late Dr. Clarke. In the last volume of his Travels—and few men had seen more of the world—he thus apostrophizes England:—

"O England, decent abode of comfort, cleanliness, and decorum! O blessed asylum of all that is worth having upon earth! O sanctuary of religion and of liberty for the whole civilized world! It is only in viewing the state of other countries that thy advantages can be duly estimated. May thy sons who have fought the good fight, but know and guard what they possess in thee. O land of happy firesides and cleanly hearths! of domestic peace, of filial piety, and parental love, and connubial joy! the cradle of heroes, the school of sages, the temple of law, the altar of faith, the asylum of innocence, the bulwark of private security and of public honour—

Where'er I roam, whatever realms to see,
My heart untravell'd fondly turns to thee."

Our own experience of the functions of this organ harmonizes with that of Dr. Spurzheim, and we feel satisfied that of the numerous individuals who have left this country for America, and lately for the Australian gold fields, the major part will be found moderately developed in Inhabitiveness and largely developed in Locality. Where it is otherwise, the probability is, that the organs of Inhabitiveness and Locality are equal in power, and when the individuals have achieved the objects of their journey, they will return with increased zest to their own country.

Emigration cannot be safely carried on where this organ is large, and Locality moderate. To be productive of all the advantages which are so frequently held out to induce persons to emigrate, the following seems to me to be the best combination:—A bilious nervous temperament, moderate Inhabitiveness, full Combativeness and Destructiveness, rather large Secretiveness, Acquisitiveness, Firmness, and Self-Esteem, with large Locality, and well-developed powers of reflection and observation. Even where the organization is so moderate, and the education so limited, as to keep the emigrants to mere hewing of wood and drawing of water, there would be misery and discontent and suffering, if Inhabitiveness were too freely developed.

THEORY AND PRACTICE OF DYEING.

CHAPTER X.

MINERAL DYE-STUFFS.

Salts of Lead.—The salts of a metal always consist of an oxide of that metal chemically combined with an acid. The particular metal, lead, to the salts of which we are in this chapter to turn our attention, combines with oxygen in four different proportions; of the four oxides of lead thus formed, it will be necessary to give some account before going further.

The first is the greyish-blue crust, formed upon the surface of lead exposed to the air. It is termed the suboxide of lead, consisting of two equivalents of lead and one of oxygen. It may be prepared artificially by burning oxalate of lead in a retort; the suboxide remains in the retort as a dark-grey powder.

The second oxide consists of lead and oxygen in equal proportions, and is therefore termed the protoxide of lead; it may be obtained by exposing metallic lead at a red heat to a current of air; the oxygen of the air combines with the lead, which then fuses. As it cools, it crystallizes in masses of a greenish-yellow colour. It is obtained on the large scale by cupellation—a process of fusion to which the ores of lead are subjected for the purpose of extracting the silver which they generally contain. When the protoxide of lead is kept for some time, it falls into a brick-red scaly crystalline powder, known in commerce as litharge. This is the principal oxide from which the salts of lead are prepared for the dyehouse; it is generally to some extent contaminated with iron, copper, and red lead, and is also subject to much adulteration in the market. Litharge of good quality possesses a crystalline lustre, and is completely soluble by digestion in nitric acid. The amount of adulteration, if it be brick-dust, may thus be ascertained, as it remains insoluble. The protoxide of lead is also obtained by adding a caustic alkali to a solution of a salt of lead; the oxide is precipitated as a white powder; it is soluble in an excess of caustic alkali, and also in solutions of the alkaline earths, as lime, with which it forms compounds more or less soluble. The protoxide is the only oxide which combines with acids.

The third oxide of lead is termed the peroxide, consisting of two equivalents of oxygen and one of lead. It may be obtained by digesting litharge in a boiling solution of chloride of lime, known as bleaching powder. It is a powder of a dark-brown colour, and is not used for preparing any salts of lead.

The fourth oxide of lead consists of three equivalents of oxygen, and four of lead. It is not usually considered to be a direct combination of oxygen and lead in these proportions, but a mixture of the second and third oxide just described in the proportion of two of the protoxide to one of the peroxide, which may be separated by digestion in dilute nitric acid: the acid combining with the protoxide, and liberating the peroxide which remains undissolved. Whether the view we have stated of its constitution be correct or not, is not our business to discuss. This oxide is not much used in the dyehouse; it is known in commerce as red lead or minium.

Nitrate of lead is prepared by dissolving litharge, or metallic lead in nitric acid, and evaporating the solution, which leaves a crystalline mass, the crystals of which are white and generally opaque, and soluble in $7\frac{1}{2}$ parts of cold water. The nitrate of lead, when prepared in this way, contains one proportion of oxide, and one of nitric acid; but by boiling the salt for some time over litharge, the acid will combine with two, three, or even six proportions of lead, forming what are termed *basic* salts. The fact just stated has been known to practical dyers for some years, and it is made available for the purpose of dyeing orange or dark shades of yellow.

Acetate of lead (sugar of lead) may be obtained by exposing metallic lead to the action of acetic acid, either as a liquid or as a vapour, and to the air: a portion of the acid is decomposed, and carbonate of lead is formed,* which is then easily decomposed by another portion of the acid; the latter, combining with the lead, forms acetate of lead, and the carbonic acid is evolved.

Acetate of lead is prepared for extensive purposes by a variety

* Carbonate of lead (white-lead) is formed on a large scale, by exposing thin sheet-lead to the vapours of vinegar.

of modes. The first we mention, is to immerse a number of sheets of lead in vinegar, so arranged that the uppermost sheets are exposed to the action of the air. When they become covered with the crust of carbonate, they are shifted to the bottom of the vat, where the acid decomposes the carbonate and forms acetate, while the succeeding sheets are being exposed to the same course of action.

Another process is to expose sheets of lead to the vapours of vinegar: the carbonate formed is collected and immersed in strong vinegar. In both these processes, when the acid appears to be saturated, or when it ceases to decompose the carbonate, the solution is drawn into proper vessels and allowed to crystallize.

Another process for preparing acetate of lead is to dissolve litharge in strong vinegar to saturation. This is done by gradually sprinkling the litharge in a vessel of vinegar subjected to a boiling heat; the vinegar is kept stirring, to prevent the adhesion of the litharge to the bottom and sides of the boiler. When a sufficient quantity is dissolved, a moderate quantity of cold water is poured into the solution, reducing it a little below the boiling point, and then it is allowed to settle; the clear fluid is drawn off into a separate vessel and allowed to crystallize. If the solution be coloured, it is whitened by filtration through bone black. Common unrectified wood vinegar or pyroligneous acid, is much used for the preparation of acetate of lead for the dye-work. It is known in the dyehouse by the appellation of *brown sugar*.

Basic salts, or subacetates, are made by boiling common acetate of lead with litharge. The tribasic acetate, a combination of three of lead to one of acid, is the best salt for dyeing orange, deep yellow, and amber. It is prepared in the dyehouse by boiling a solution of sugar of lead with litharge and adding to this a little lime. The proportions, however, vary in different dyehouses. Those which ought to be employed to produce the tribasic acetate, are six parts of crystallized acetate of lead, eight of litharge, and thirty of water, boiled till the litharge is dissolved. The addition of lime causes a loss, as the lime combines with part of the acetic acid forming acetate of lime, which, if these proportions have been used, would prevent some of the litharge from being dissolved. If the mixture be not long enough boiled, or if the proportion of litharge be too small, the adoption of lime insures the conversion of the acetate of lead present into the tribasic state, though it is to be observed, that this will be at the expense of a portion of the lead intended for producing the colour. We have experienced much annoyance from this source; and it is well known in the trade, that when the lead is hastily prepared for orange, it is a cause of great anxiety, and the colour obtained is frequently defective. As this is rather an important point in the economy of the dyehouse, we shall explain our view of the matter. If the proportions recommended above be used, the following is the result: and we must bear in mind that while the oxide of lead forms the basis of the dye, the acid merely holds the lead in solution. The six pounds of acetate of lead is composed of four lbs. oxide of lead, and two lbs. acetic acid; but when the eight pounds of litharge is dissolved or, as dyers say, taken up, the tribasic salt will consist of 12 lbs. of oxide of lead and 2 lbs. of acetic acid; that is, every ounce of acid holds in solution twelve ounces of oxide of lead. Now, if a little lime, as we have often remarked, be put in along with the litharge, the result will be as follows: Suppose that 50 lbs. of cotton is to be dyed orange, and that it consumed the 6 lbs. acetate of lead prepared as now stated, to give it a good colour. If $1\frac{1}{2}$ ounces of lime be mixed in, it will combine with three ounces of acid: in this way 36 ounces of oxide of lead is not taken up, and is therefore ineffective in the production of the colour; while at the end of the process, the dyer is surprised to find his colour poor. We may notice that lead in the basic state is not held in combination by a very great affinity, and thus a very little counteractive influence precipitates it. The presence of sulphates or carbonates in the water, which almost all water contains, precipitates the lead; hence the reason that when the clear acetate solution is poured into a tub of water, the contents become milk-white by the formation of an insoluble carbonate. This is all lost for the time being, as it is rendered insoluble and useless as a dye. Every ounce of carbonate renders useless 5 ounces of lead. The softest water should be used for the lead solution, as, for example, the condensed steam from an engine. Before explaining the methods of dyeing with the salts of lead, it will be necessary to give some account of the salt, bichromate of potash, which is used in connection with the salts of lead.

Bichromate of potash (chrome) is a salt composed of the oxide of chromium and potash. Chromium, which is a metal, is obtained abundantly from certain iron ores, called "chrome iron-ore," in America, in different parts of the Continent of Europe, in Shetland, and in Fifeshire in Scotland.

Chromium combines with oxygen in two proportions: the first is termed the oxide of chromium, and is composed of two of metal and three of oxygen. It has a beautiful green colour; it may be obtained by heating to redness a mixture of bichromate of potash and sal-amoniac. When the mixture is cool, it is thoroughly washed with boiling water, and the oxide remains as a green powder.

The second combination of oxygen with chromium, is one of metal with three of oxygen. This compound is a powerful acid termed chromic acid; it is crystalline, and possesses a beautiful deep orange colour. Various methods have been proposed for preparing this acid; the following, by Mr Robert Harrington, is probably the most simple: "Take 100 measures of a cold saturated solution of bichromate of potash (prepared by boiling, and then allowing the solution to cool and deposit the excess of the salt), and add to this from 120 to 150 measures of concentrated sulphuric acid; the latter should be free from sulphate of lead, as otherwise it would fall as chromate and sulphate of lead with the chromic acid on dilution with the bichromate. The mixture is then allowed to cool, and the chromic acid gradually crystallizes in beautiful dark crimson needles. Decant the fluid part, and place the crystals with the adhering sulphuric acid on a thick flat tile of biscuit porcelain: another tile is then to be placed upon the crystals, and the whole submitted to a pressure for a considerable time. On removing the chromic acid it will be found in a perfectly dry state, and yielding a mere trace of sulphuric acid on examination."*

Chromic acid may also be prepared from the chromate of lead, which results from the mixture of a salt of lead and bichromate of potash at the bottom of the *chrome tubs* used in dyeing yellows. Two parts of strong sulphuric acid being added to one part of dry chromate of lead slightly heated, and allowed to stand for about twelve hours; water is then added, when the lead is precipitated as a sulphate, and the chromic acid mixed with a little sulphuric acid remains in solution. The liquid is decanted and evaporated at a boiling heat; on cooling, the greater portion of the chromic acid separates in beautiful carmine-red crystals. If the process be carefully conducted, a great portion of what is now little better than thrown away, might be made useful by a trifling addition of expense.

Chromic acid combines with the different bases, and forms a series of important salts. With potash it combines in two proportions, forming what is termed the yellow and the red chromate of potash. The yellow chromate of potash may be prepared by adding to 2 lbs. of red chromate one pound of caustic potash; it crystallizes in small crystals of a rich deep lemon colour, composed of one proportion of acid with one of potash. This salt is not much used in the arts.

The bichromate, or red chromate, of potash, may be prepared from the yellow chromate by adding a little sulphuric acid to it, which combines with a portion of the potash, leaving two proportions of chromic acid in union with one proportion of potash, which crystallizes in large square tubular crystals of a rich orange-red colour. This is the salt used in the arts, not only for dyeing, but for the preparation of other chrome compounds, and is prepared on the large scale in the following manner: the chrome iron ore, after being finely ground and sifted, is mixed with a quantity of dried nitre and carbonate of potash. This mixture is thrown into a reverberating furnace, and subjected for several hours to a powerful heat, being occasionally stirred. When perfectly calcined, the mass is raked out and dissolved in water. It is then boiled for several hours, after which the insoluble portion is allowed to settle and the solution decanted, which is evaporated, and leaves crystallized the yellow chromate of potash. The chemical changes which take place in the furnace are these: first, the decomposition of the nitre giving of oxygen, which combines with the oxide of chromium and forms chromic acid; this unites with the potash of the nitre and of

* Proceedings of the Chemical Society, vol. i.

the carbonate, and forms the yellow salt which is soluble in water, and afterwards separated as described. It contains also soluble impurities, such as caustic potash, silicate and aluminate of potash, which are separated by the succeeding operations of boiling and crystallization.

The bichromate, which is the salt used in dyeing, is prepared from the yellow obtained as above. Into a concentrated solution of the yellow salt is poured acetic, or sulphuric acid. The latter acid, though often used, is not well adapted for the purpose, as the sulphate of potash formed is most difficult to separate from the chromate, and constitutes a serious adulteration. Acetic acid is preferable, and is now generally employed. The quantity of the acid used is so regulated, that it combines with the one half of the potash in the yellow salt, leaving two proportions of chromic acid in union with the other half; this process may be expressed thus:—

2 Yellow salt	2 chromic acid	Bichromate of potash.
	1 potash	
	1 potash	Acetate of potash.
1 Acetic acid		

The solution of yellow salt being concentrated before the addition of the acid, the bichromate formed has not so much water as to hold it in solution, and is therefore thrown down as an orange-coloured powder. This is carefully collected, dissolved again in water, and crystallized by slow evaporation.

The bichromate of potash, when sulphuric acid has been used, is sometimes adulterated to about 40 per cent. This is easily detected by dissolving a small quantity of the salt in distilled water, and adding to it pure nitric acid; after which, there is added a little solution of nitrate of barytes. If any sulphate be present, there will be formed on the addition of this salt, a white precipitate, insoluble in acids; if any muriate be present, the addition of a solution of nitrate of silver to the salt similarly prepared, gives a white curdy precipitate.

Soda is sometimes used instead of potash in the preparation of the salt of chrome, and serves the purpose of the dyer equally well. The combination of chromic acid with other bases is effected by decomposing the bichromate with the salt of the particular base wanted. For example, to prepare the chromate of lead a soluble salt of lead, such as the acetate, is added to a solution of bichromate, a double reaction takes place, and there is formed a soluble salt of potash, and an insoluble salt of lead.

2 Chromate of lead	2 oxide of lead	Subchromate of lead
	1 chromic acid	
	1 chromic acid	Chromate of potash.
2 Potash	1 potash	
	1 potash	Potash.

This chromate of lead is a rich lemon-yellow powder, which constitutes the chrome yellow dye. If this powder be digested in hot caustic potash, it is partially decomposed: the potash unites with one proportion of the chromic acid, and there is formed a basic salt of lead thus:—

2 Acetate of lead	1 acetic acid	Acetic acid
	1 acetic acid	Acetate of potash.
	2 oxide of lead	
1 Bichromate of potash	1 potash	Chromate of lead.
	2 chromic acid	

The subchromate of lead, prepared in this way, is of a deep orange colour, approaching to scarlet, and constitutes the chrome orange dye upon cotton.

The subchromate of lead, prepared in the following manner, has a rich vermilion red colour, greatly superior to that obtained upon cotton by the process of dyeing. Having fused a quantity of nitre in a crucible, add gradually dry chromate of lead, so long as effervescence and escape of red fumes take place. The crucible being then taken off and allowed to settle, the melted portion is poured off, leaving the heavy powder at the bottom, which may be washed with a very little water.

The salts of these two metals, lead and chromium, have completely superseded the use of vegetable dye-stuffs for the dyeing of yellows, oranges, and most kinds of greens upon cotton. To dye a yellow, the goods are immersed or wrought through a solution of nitrate or acetate of lead, or more generally, a mixture of these, after which the solution is wrung tightly out, and the goods passed through a solution of bichromate of potash, then passed again through the lead solution, and washed and dried. The proportions of the two salts vary according to the particular hue and depth of colour wanted, and for deep shades the goods are passed several times through *lead* and *chrome*. The proportions now used in the dyehouse are, for dyeing a lemon yellow, 10 lbs. of cotton, 4 oz. of nitrate, 5 oz. of lead, 12 oz. of sugar of lead, and 6 oz. of chrome. If the shade is to be a little darker, 5 oz. nitrate of lead, and 11 oz. acetate or sugar of lead, and $6\frac{1}{2}$ oz. bichromate; a very red shade of yellow requires 8 oz. nitrate and 8 oz. acetate of lead, with 14 oz. of chrome. When dark ambers are wanted, the proportion of nitrate to the acetate of lead is increased, but the last is the highest proportion of bichromate to the quantity of lead, and we need hardly say that it is just so much wasted. The proper proportions for dyeing yellow, even were the salts of lead entirely absorbed by the goods, is as near as possible one-half bichromate of potash to the lead, whether nitrate or acetate be used. All above that is direct loss, and as the salt of lead is never all taken up by the cotton, the proportion of chrome may be less than the half weight of lead used. However, it may be said that practice has dictated these quantities, and the results of practice are more to be relied upon than theory. Whether then, is the theory or practice in this case at fault? It will be observed that the depth of redness of the shade is in proportion to the amount of nitrate of lead used, and that it is the oxide of lead in the acid which gives the dye with the chromic acid of the bichromate of potash. Now every 100 ounces of nitrate of lead contains about $67\frac{1}{3}$ ounces of oxide of lead, and every 100 ounces of acetate of lead contains about $68\frac{1}{2}$ oxide of lead; hence the same weight of acetate of lead should give a richer dye, and take up in proportion a little more bichromate of potash than the nitrate, so that the practice of giving more bichromate of potash with nitrate of lead must be an error. It appears that the extra quantity is given for the purpose of reddening the hue of the yellow. How this is effected will be seen presently. When a piece of cloth is put into acetate or nitrate of lead, the cloth is merely soaked with the salt, there is no fixing of the oxide upon it; and if put through water, it would be completely washed off. In this state therefore the salt cannot form a dye, it must be rendered insoluble. This is effected, as we have observed above, by immediate transposition from the salt of lead into the bichromate of potash, where there is formed the insoluble chromate of lead. That portion of the salt which obtains within the hollow fibres of the cotton becomes fixed, but all that is upon the goods external to the fibres is loose, and either falls off in the chrome tub or is washed off after. This portion probably constitutes one half, creating so much loss; and it is well known that where chrome yellow dyes are produced to a great extent, the chromate of lead thus formed is collected, amounting in a short time to hundred-weights, and sold at a trifle to painters. But there is another evil attending this method. Say 100 lbs. of yarn is to be dyed a red shade of lemon, this will take 160 ounces of the salt of lead, which will contain 53 ounces of acid and 107 oxide of lead. If we suppose that all the lead salt is taken up by the goods, which is seldom the case, the 160 ounces should take only 73 ounces of bichromate of potash, though in practice they take 140 of bichromate. Now what is the result?

160 Nitrate or acetate of lead	107 oxide of lead	Chromate of lead.
	$26\frac{1}{2}$ acid	
	$26\frac{1}{2}$ acid	Free acid.
73 Bichromate of potash	$50\frac{1}{4}$ chromic acid	
	$22\frac{3}{4}$ potash	Salt of potash.

leaving 67 of bichromate of potash to be acted upon by the free acid for the purpose of giving a red shade. Surely something cheaper might be had.

The deleterious effects of free nitric acid in the chrome will be evident, by adding a few drops of nitric acid to a strong solution of bichromate of potash; the colour remains unchanged. Dip a piece of white paper in this, and it is coloured dark orange: expose it to the air, and in 15 minutes the colour has entirely disappeared. A similar change is effected upon the goods with the bichromate upon them when taken out of the tub, and ex-

posod to the air previous to being passed through the solution of lead.

All these evils might be obviated by a little attention to principles. We have said that it is the oxide of lead which forms the die with the chromic acid. This oxide is insoluble, and could be fixed in this state in the goods previous to immersion into the chrome tub. It could be better effected by passing the goods from the solution of lead, through a tub full of water in which is dissolved a small quantity of soda or potash; this takes up the acid of the lead salt and leaves the insoluble oxide in the fibre. If this be put through the bichromate of potash it gives a very dull yellow, as the affinity of the chromic acid for the lead is prevented from exercising its power by the potash which is in union with it; but if, previous to putting in tbe goods, a few drops of sulphuric acid be added to the chrome solution, the chrome acid is set free, and combines freely with the oxide of lead upon the cloth, giving a beautiful yellow. If a red shade be wanted, a little exposure to the air before finishing from tho lead will effect it, and a saving will be made.

Chrome greens are dyed in the same manner as the yellow, the goods being previously dyed blue by means of the blue vat. For dyeing green, nitrate of lead is never used, as anything that tends to redden the hue is carefully avoided, so that the goods are not allowed to stand for any time out of the solution of the bichromate; yet with all tbe care that is used there is much difficulty in avoiding brown blotches and light parts. This has been alluded to in a preceding article; but we may add here, that if the lead were reduced to the state of an oxide upon the goods previous to being put into the bichromate of potash, and no acid added to the chrome solution, there would be neither brown nor light parts upon the goods, and witb ordinary care tbe colour would be perfectly uniform.

Chrome orange is obtained by fixing upon the goods the subchromate of lead, described in a previous part of this paper. This is effected by dyeing the goods a deep yellow, and passing them through a strong hot alkaline solution, which combines with a portion of the chromic acid, and leaves the subchromate of lead upon the cloth. But the method of dyeing the yellow for this purpose is more consistent than the ordinary process for producing a yellow. We have already alluded to the preparation of the *sub* or basic salts of lead, and to tbe proper proportions and the method of obtaining them, with their use in dyeing, in preference to the ordinary salt for heavy colours. We will now give the method of preparing them in the dye-house, with the ordinary method of dyeing orange.

To dye a hundred pounds weight of cotton, 30 lbs. of brown sugar of lead, and 17 lbs. of litharge, are put into a boiler with about 12 gallons of water, and boiled together for an hour or so, until the litharge is dissolved; then a quantity of lime, from one to two pounds, is added, any sediment is allowed to settle, and the clear fluid drawn off and put into a tub for the purpose; 12 lbs. bichromate of potash is dissolved in another tub. Two other tubs, capable of allowing 10 lbs. of yarn to be wrought in them with freedom, are filled, one with water, to which a little solution of lead is added, and the other with lime-water; 10 lbs. of the yarn (a bundle) is now wrought for some time through the tub containing the lead, wrung out and put through the lime-water. a little more lead is added, another bundle is passed through the same tub, renewing the lime-water each time. The whole are operated upon two or three times, according to the depth of orange wanted. The bundles are next put through a tub of water, to which is added some of the solution of bichromate of potash, and then through the lead solution. The solution of lead is generally renewed at this stage of the operation. After being all put through, they are again passed through the chrome. A saturated solution of newly dissolved lime is brought to the boiling point, the yarn is now wrought in this, either by drawing some off in tubs, or by the most convenient method that circumstances will allow, until the colour is changed to a deep orange or scarlet. It is then taken out, passed through another tub filled with boiling hot water, to which is added a small quantity of a solution of soap, soda, and oil, wrung out and dried at a high temperature. The *raising* of the orange, as the hot liming is termed, is the most trying operation. If the lead has not been properly prepared, or if there be any mismanagement in the operation of fixing it upon the fibre, the hot lime will take all tbe colour off, leaving but a red salmon shade, or it may come off in parts. Several causes operate to produce these results, which we have not space to detail here at present. Oranges being once done wrong, they are very difficult to recover.

Bichromate of potash has been very extensively used of late as a mordant for a variety of colours upon woollen, and is entirely superseding several of the old processes of dyeing many of the ordinary shades, which were very tedious in manipulation.

ON LATHE SPEED-PULLEYS.

Article II.—(*Concluded.*)

The following table for facilitating the calculation of cones and speed-pulleys, with examples of its practical application, are an abridgment of a paper, containing a minute and lengthened investigation, with the view of finding a general formula for the above purpose. As the table, with its formula, is the result of the investigations, we deem it unnecessary to insert more of the calculations.

Let the ratio of the radii of the required pulleys (fig. 5, p. 330) be as 1 to ϕ; let x be the radius (B h) of the greater, so that $\phi\, x$ will be the radius (A a) of the less. Also, let D be the distance (A B) between the centres of the shafts; $\pi = 1\cdot5709$; L = the half length of the band ($c\,a\,h\,d$). Then the part of L ($h\,i\,d$) in contact with the greater pulley will be denoted by $\pi\, x + x \sin^{-1} \frac{(1-\phi)\,x}{D}$; tbe part ($c\,a$) in contact with the smaller pulley will be expressed by $\pi\,\phi\, x - \phi\, x \sin^{-1} \frac{(1-\phi)\,x}{D}$; and the part between the pulleys will be $(D^2 - (1-\phi)^2\, x^2)^{\frac{1}{2}}$. Adding these parts, we have this equation

$$(1)\quad \pi\,(1-\phi)x + (1-\phi)x \sin^{-1} \frac{(1-\phi)x}{D} + (D^2 - (1-\phi)^2 x^2)^{\frac{1}{2}} = L.$$

Having arrived at this equation, the writer proceeds to expand the two last terms of the first side; thence he deduces a value of x, in the form of an infinite series. But though, as he remarks, the methods which he gives lead to exact or very nearly exact results, they are attended with too much arithmetical computation to be sufficiently ready of application when the necessity of such calculations is of frequent occurrence. What is wanted is an expeditious and easy solution rather than one accurate to a great number of decimal places. He then submits the following table as a substitute constructed upon the ground of the foregoing formula: Let z be the are, the sine of which is $\frac{(1-\phi)\,x}{D}$. Hence $x = \frac{D \sin z}{1-\phi}$ and $(D^2 - (1-\phi)^2 x^2)^{\frac{1}{2}} = D \cos z$.

Substituting these in the equation already given, and dividing by D, we have

$$(2)\qquad \frac{\pi\,(1+\phi)}{1-\phi} \sin z + z \sin z + \cos z = \frac{L}{D}$$

The object of the table is to afford a ready solution of the equation (2). The column marked A, contains the value of the expression $\pi \sin z$, z being supposed equal to the number of degrees placed opposite it in the first column. Thus if z is 10° we obtain $\pi \sin z = \cdot27277$ in the column marked A, opposite 10° in the column marked Z. The third column, headed Δ, contains the difference of each successive pair of values of $\pi \sin z$, reckoning by tenths of a degree; and it is obvious that for any intermediate angle as 2·6°, the corresponding value of A will be found by adding to the value of A for 2°, the sum of the differences in the sub-columns Δ, under the heads ·1° to ·6°; that is,

$$\cdot05482 + 274 \text{ repeated six times} = \cdot07126^{\circ}$$

Its use is also to proportion for smaller parts of a degree than are set down in the table, as in the common trigonometrical tables. The column marked B, contains the values of the expression $z \sin z + \cos z$ for every value of z in the first column; and the fifth column marked δ, contains the differences of these values similarly to the third column. The numbers in the first

Table to Facilitate the Calculation of Cones and Speed-Pulleys.

Z	A	Δ Successive Differences of the Values of A for Tenths of a Degree.										B	δ Successive Differences of the Values of B for Tenths of a Degree.									
		·1°	·2°	·3°	·4°	·5°	·6°	·7°	·8°	·9°	1·0°		·1°	·2°	·3°	·4°	·5°	·6°	·7°	·8°	·9°	1·0°
0°	·00000	274	274	274	275	274	274	274	274	274	274	1·00000	0	1	0	1	2	1	2	3	2	3
1	·02741	275	274	274	274	274	274	274	274	274	274	1·00015	3	4	4	4	4	5	5	5	6	6
2	·05482	274	274	274	274	274	274	273	274	274	274	1·00061	6	7	7	7	7	8	8	8	9	9
3	·08221	274	273	274	274	273	274	274	273	274	273	1·00137	9	10	10	10	10	11	11	12	11	12
4	·10957	274	273	274	273	273	274	273	273	273	273	1·00243	13	12	13	13	14	14	14	14	15	15
5	·13690	273	274	273	273	272	273	273	273	273	272	1·00380	15	16	16	16	17	17	17	17	18	18
6	·16419	273	273	272	273	272	272	273	272	272	272	1·00547	18	19	19	19	19	20	20	21	21	21
7	·19143	272	272	272	272	272	272	272	271	272	271	1·00744	21	21	22	23	22	23	23	23	24	24
8	·21861	272	271	271	272	271	271	271	271	271	271	1·00970	24	25	25	25	25	26	26	27	26	27
9	·24573	270	271	271	270	271	270	270	270	271	270	1·01226	27	28	28	28	28	29	29	29	30	30
10	·27277	270	269	270	270	269	270	269	270	269	269	1·01512	30	30	31	31	31	32	32	32	32	33
11	·29972	269	269	269	269	269	268	269	268	268	269	1·01826	33	33	34	34	34	35	35	35	36	35
12	·32659	268	268	268	268	267	268	267	268	267	267	1·02169	36	36	37	37	37	37	37	38	39	38
13	·35335	267	267	267	267	267	267	266	267	266	266	1·02541	39	39	39	40	39	41	40	41	41	41
14	·38001	266	266	266	265	266	265	265	265	265	265	1·02941	41	42	42	43	42	43	43	44	43	44
15	·40655	265	265	264	264	265	264	264	264	263	264	1·03368	45	44	45	45	46	45	46	46	47	46
16	·43297	263	264	263	263	263	263	262	263	262	263	1·03823	47	48	47	48	48	48	49	49	49	49
17	·45926	262	262	262	261	262	261	261	262	260	261	1·04305	50	50	50	51	50	51	51	52	52	52
18	·48540	261	260	261	260	260	260	260	259	259	260	1·04814	52	53	52	53	54	53	54	54	55	54
19	·51140	259	259	259	259	258	259	258	258	258	257	1·05348	55	55	55	56	56	56	56	57	56	58
20	·53724	258	257	258	257	256	257	257	256	256	256	1·05908	57	58	58	58	58	59	59	59	59	60
21	·56292	256	256	255	256	255	255	255	254	255	254	1·06493	60	60	60	61	61	61	61	62	62	62
22	·58843	254	254	254	253	254	253	253	253	252	253	1·07102	63	62	63	63	63	63	64	64	64	64
23	·61376	252	252	252	252	251	252	252	251	250	251	1·07735	65	65	65	65	66	66	66	66	67	67
24	·63890	250	250	250	249	250	249	249	249	249	249	1·08392	67	67	67	68	68	68	68	68	69	69
25	·66385	248	248	248	248	248	247	247	247	247	246	1·09071	69	69	70	70	70	70	70	71	71	71
26	·68859	246	247	245	246	246	245	245	245	244	245	1·09772	71	72	72	72	72	72	73	72	73	73
27	·71313	245	244	244	243	243	243	243	243	242	242	1·10494	74	73	74	74	74	75	74	75	75	75
28	·73744	242	242	242	241	241	241	240	241	240	240	1·11237	76	75	76	76	76	77	76	77	77	77
29	·76154	239	240	239	239	239	238	238	238	238	238	1·12000	78	77	78	78	78	78	79	79	78	79
30	·78540	237	237	237	237	236	236	236	236	235	235	1·12782	80	79	80	80	79	81	80	80	81	81
31	·80902	235	234	235	234	234	234	233	233	233	233	1·13583	81	81	82	81	82	82	82	82	83	82
32	·83240	233	233	232	231	232	231	231	230	231	230	1·14401	83	83	83	83	83	84	84	84	84	84
33	·85552	230	229	229	229	229	229	228	228	227	228	1·15236	84	85	85	85	85	85	85	85	86	86
34	·87838	227	227	226	227	226	226	225	225	225	225	1·16087	86	86	86	87	86	87	87	87	87	87
35	·90097	225	224	224	223	224	223	222	223	222	222	1·16953	87	88	88	87	88	89	88	88	89	88
36	·92329	222	221	221	221	221	220	220	219	220	219	1·17833	89	89	89	89	90	89	90	89	90	90
37	·94533	219	218	218	218	218	217	217	217	217	216	1·18727	90	90	91	90	91	90	91	91	91	91
38	·96708	216	215	216	215	214	215	214	214	213	213	1·19633	92	91	91	92	92	92	92	92	92	92
39	·98853	213	213	212	212	212	211	211	211	211	210	1·20551	92	93	93	92	93	93	93	93	93	93
40	1·00969	210	209	209	209	209	208	208	208	207	208	1·21479	94	93	94	94	93	94	94	94	94	95
41	1·03054	206	207	206	206	205	205	205	205	204	204	1·22418	94	94	95	94	95	95	94	95	95	95
42	1·05107	203	204	203	202	202	202	202	201	201	201	1·23364	95	96	95	95	96	95	96	95	96	96
43	1·07128	200	200	200	199	199	199	199	198	197	198	1·24319	96	95	96	96	97	95	97	96	97	96
44	1·09117	197	196	197	196	196	195	195	195	194	194	1·25280	96	97	96	97	97	96	97	97	97	97
45	1·11072	194	193	193	193	192	192	192	191	191	191	1·26247	97	97	97	97	97	97	97	98	97	97
46	1·12994	190	190	189	190	189	188	188	188	188	187	1·27218	97	98	97	98	97	98	97	98	97	98
47	1·14881	187	186	186	186	185	185	185	184	184	184	1·28193	98	97	98	98	98	97	98	98	98	98
48	1·16733	183	183	183	182	182	181	181	181	180	181	1·29171	97	98	98	98	98	98	98	98	98	98
49	1·18550	179	180	178	179	178	178	178	177	177	176	1·30150	97	98	98	98	98	98	98	98	98	98
50	1·20330	176	176	175	175	175	174	174	173	173	173	1·31129	98	98	97	98	98	98	98	98	97	98
51	1·22074	172	172	172	171	171	170	170	170	169	169	1·32107	98	98	97	98	98	97	98	98	97	98
52	1·23780	169	168	168	168	167	166	167	166	165	165	1·33084	97	98	97	98	97	97	98	97	97	97
53	1·25449	165	165	164	163	164	162	163	162	162	161	1·34057	97	97	98	97	97	96	97	97	97	97
54	1·27080	161	161	160	160	159	159	159	158	158	157	1·35027	96	97	96	97	96	97	96	96	96	97
55	1·28672	157	157	156	156	155	156	154	155	153	154	1·35991	96	96	96	95	96	96	96	95	96	95
56	1·30225	153	153	152	152	151	152	150	151	150	149	1·36948	95	96	95	95	95	95	95	95	94	95
57	1·31738	149	149	148	148	148	147	146	147	146	145	1·37898	95	94	94	95	94	94	94	94	93	94
58	1·33211	145	145	144	144	143	143	143	142	142	142	1·38839	94	93	93	94	93	93	93	93	93	92
59	1·34644	141	140	140	140	139	139	139	138	138	137	1·39770	93	92	92	92	92	92	92	92	92	91
60	1·36035	137	136	136	136	135	135	134	134	134	133	1·40690	91	91	92	91	90	91	91	90	90	90
61	1·37385	133	132	132	131	131	131	130	130	129	129	1·41597	90	90	90	90	89	89	90	89	89	88
62	1·38693	129	128	127	128	127	126	126	125	125	125	1·42491	89	88	89	88	88	88	87	88	87	87
63	1·39959	124	124	123	123	123	122	122	121	121	120	1·43370	87	87	87	87	86	86	86	86	86	85
64	1·41182	120	120	119	119	118	118	117	117	116	116	1·44233	86	85	85	85	85	84	84	84	84	84
65	1·42362											1·45079										

column denote a set or series of arcs or angles, advancing by equal differences of one degree from 0° to 65°, those in the second and fourth columns are the corresponding values of $\pi \sin z$, and $z \sin z + \cos z$. In speaking of these numbers, we shall call any one taken from the column marked A, A; that opposite it in the column marked B, B; and that opposite it in the column marked Z, z. We have therefore from the equation (2);

$$\frac{1+\phi}{1-\phi}\text{A}+\text{B}=\frac{\text{L}}{\text{D}};$$

so that if we find in this table, any number, B, which added to the product of its corresponding number, A, multiplied by $\frac{1+\phi}{1-\phi}$, is equal to $\frac{\text{L}}{\text{D}}$, we shall find the angle z opposite in the first column. Thus, if $\frac{\text{L}}{\text{D}}=1{\cdot}66553$ and $\frac{1+\phi}{1-\phi}=3$, we will find $z=8°$, for at that value of z, $\text{A}\times\frac{1+\phi}{1-\phi}+\text{B}=3\times{\cdot}21861+1{\cdot}00970=1{\cdot}66553$.

The point then is, amongst all these numbers how are we to hit upon the right set? we might try a great many before alighting on the proper one. There is, however, in reality very little difficulty in this. Form an estimate, however rough, to find by a few trials the angle z, and the error of this estimate will be given by this formula,

$$z=\frac{\frac{\text{L}}{\text{D}}-\left(\frac{1+\phi}{1-\phi}\text{A}+\text{B}\right)}{\left(10\,\frac{1+\phi}{1-\phi}\Delta+\delta\right)}$$

If we have guessed or assumed z near the truth, z will be very small. On the other hand, if we find z to be considerable, it will be necessary to repeat the process, taking $z'=z+z$ and the corresponding numbers A′ and B′, and the same formula will give the new correction; and this must be continued till no further correction is necessary. To make this clear by an example: Suppose $\text{D}=36$ inches, $\text{L}=87{\cdot}7256$, and $\phi=\frac{1}{6}$; we have therefore $\frac{\text{L}}{\text{D}}=2{\cdot}43682$ and $\frac{1+\phi}{1-\phi}=\frac{7}{5}$. There being a considerable difference in the sizes of the pulleys, and their centres being near each other, the angle z must be considerable; say 10°. Take $z=10°$; we have, from the table opposite $z=10$, $\text{A}={\cdot}27277$ and $\text{B}=1{\cdot}01512$, also the differences (which, considering the angle as likely to increase, ought to be taken between z and the next higher) $\Delta={\cdot}00270$ and ${\cdot}00030=\delta$. These substituted in the formula, give

$$z=\frac{2{\cdot}43682-\left\{\frac{1+\frac{1}{6}}{1-\frac{1}{6}}\times{\cdot}27277+1{\cdot}01512\right\}}{10\left\{\frac{7}{5}\times{\cdot}00270+{\cdot}00030\right\}}=25°$$

Hence $z'=z+z=10°+25°=35°$.

Repeating the operation: for $z'=35°$ we have from the table, $\text{A}={\cdot}90097$, $\text{B}=1{\cdot}16953$, $\Delta={\cdot}00225$ and $\delta={\cdot}00087$, therefore

$$z=\frac{2{\cdot}43682-\left\{\frac{7}{5}\times{\cdot}90097+1{\cdot}16953\right\}}{10\left\{\frac{7}{5}\times{\cdot}00225+{\cdot}00087\right\}}=0°{\cdot}1475=8'51''.$$

Therefore $z''=z'+z'=35°+8'\,51''=35°\,8'\,51''$.

Here, though our first estimate of z was no less than 25° in error, two applications to the table have been sufficient. Sometimes three, but in general two, will be found after a little practice to bring the result as near the truth as can be got by this means. However erroneous the first assumption may be, the result will ultimately come out correct, though with more trouble, than if it had been nearer the truth.

Having found z, x, or the radius, is given by the formula (8) as already noticed. As this requires a table of sines, and as one is not always at hand, we may use the column A of the table for that purpose. For as $\text{A}=\pi\sin z$, $\sin z=\frac{\text{A}}{\pi}$, and therefore, $x=\frac{{\cdot}63662\times\text{A}\times\text{D}}{1-\phi}$. Thus, in the preceding example $z=35°\,8'\,51''$: For $z=35°\,6'$, we find by the table $\text{A}={\cdot}90322$. The proportional part for $2'\,51''={\cdot}00106$. Therefore for $z=35°\,8'\,51''$ we have $\text{A}={\cdot}90428$, and by the above formula

$$x=\frac{{\cdot}63662\times{\cdot}90428\times 36}{1-\frac{1}{6}}=24{\cdot}869\text{ inches.}$$

If $\frac{\text{L}}{\text{D}}$ is greater than 3·14159 the problem is mechanically impossible, for at that value of $\frac{\text{L}}{\text{D}}$, the peripheries of the two pulleys come into contact, and for any greater value of $\frac{\text{L}}{\text{D}}$, they would intersect each other.

To conclude with another example of the use of the table. Let $\text{L}=84$ inches; $\text{D}=30$ inches; and suppose we wish to find a pair of cones the pulleys of which shall have the ratios of 4 to 1, 8 to 1, 12 to 1, and 16 to 1.

Here $\frac{\text{L}}{\text{D}}=2{\cdot}8$; and we have first, $\phi=\frac{1}{4}$, therefore $\frac{1+\phi}{1-\phi}=\frac{1+\frac{1}{4}}{1-\frac{1}{4}}=\frac{5}{3}$. Supposing z to be 30°, the table gives $\text{A}={\cdot}78540$; $\text{B}=1{\cdot}12782$; $\Delta={\cdot}00237$ and $\delta={\cdot}00080$; then by the formula,

$$z=\frac{2{\cdot}8-\left\{\frac{5}{3}\times{\cdot}7854+1{\cdot}12782\right\}}{10\left\{\frac{5}{3}\times{\cdot}00237+{\cdot}00080\right\}}=7°{\cdot}6\ \therefore z'=30°+7°{\cdot}6=37°{\cdot}6$$

Turning to the table, for $z'=37°{\cdot}6$, we find $\text{A}={\cdot}95841$; $\text{B}=1{\cdot}19269$, $\Delta={\cdot}00217$; and $\delta={\cdot}00091$.

$$\therefore z=\frac{2{\cdot}8-\left\{\frac{5}{3}\times{\cdot}95841+1{\cdot}192611\right\}}{10\cdot\left\{\frac{5}{3}\times{\cdot}00217+{\cdot}00091\right\}}=0°{\cdot}2199,\ \therefore z''=37°{\cdot}6+0°{\cdot}2199=37°{\cdot}8199.$$

This must be near the true value of the angle sought; but to be satisfied of it we may refer to the table once more, and for $z''=37°{\cdot}8$, we find, $\text{A}={\cdot}96275$; $\text{B}=1{\cdot}19451$; $\Delta={\cdot}00217$; $\delta={\cdot}00091$.

$$\therefore z=\frac{2{\cdot}8-\left\{\frac{5}{3}\times{\cdot}96275+1{\cdot}19451\right\}}{10\left\{\frac{5}{3}\times{\cdot}00217+{\cdot}00091\right\}}=0°{\cdot}02009,\ \therefore z''=37°{\cdot}8+0°{\cdot}02009=37°{\cdot}82009=37°\,49'\,12.''$$

For the second pair of pulleys, $\phi=\frac{1}{8}$, $\therefore\frac{1+\phi}{1-\phi}=\frac{9}{7}$. Assume $z=40°$, and the table gives $\text{A}=1{\cdot}00969$; $\text{B}=1{\cdot}21479$; $\Delta={\cdot}00210$; $\delta={\cdot}00094$.

$$\therefore z=\frac{2{\cdot}8-\left\{\frac{9}{7}\times 1{\cdot}00969+1{\cdot}21479\right\}}{10\left\{\frac{9}{7}\times{\cdot}00210+{\cdot}00094\right\}}=7°{\cdot}9,\ \therefore z'=40°+7°{\cdot}9=47°{\cdot}9.$$

Returning to the table; for $z'=47°{\cdot}9$, we find $\text{A}=1{\cdot}16549$ $\text{B}=1{\cdot}29073$; $\Delta={\cdot}00184$; $\delta={\cdot}00098$

$$\therefore z' = \frac{2\cdot8 - \left\{\frac{9}{7}\times1\cdot16549+1\cdot29073\right\}}{10\ \left\{\frac{9}{7}\times\cdot00184+\cdot00098\right\}} = 0^\circ\cdot3,\ \therefore z'' = 47^\circ\cdot9$$

$+\,0^\circ\cdot3 = 48^\circ\cdot2.$

For $z'' = 48^\circ\cdot2$ the table gives $A = 1\cdot17099$; $B = 1\cdot29366$; $\Delta = \cdot00183$; $\delta = \cdot00098$.

$$\therefore z'' = \frac{2\cdot8 - \left\{\frac{9}{7}\times1\cdot17099+1\cdot29366\right\}}{10\ \left\{\frac{9}{7}\times\cdot00183+\cdot00098\right\}} = 0^\circ\cdot02342,\ \therefore z''=48^\circ\cdot2$$

$+\,0^\circ\cdot02342 = 48^\circ\cdot22342 = 48^\circ\cdot13'\,24''.$

Proceeding to the third pair of pulleys, we have $\phi = \frac{1}{12}$, and $\frac{1+\phi}{1-\phi} = \frac{13}{11}$; we may begin by assuming $z = 53^\circ$; for which the table gives $A = 1\cdot25449$; $B = 1\cdot34057$; $\Delta = \cdot00165$; $\delta = \cdot00097$.

$$\therefore z = \frac{2\cdot8 - \left\{\frac{13}{11}\times1\cdot25449+1\cdot34057\right\}}{10\cdot\ \left\{\frac{13}{11}\times\cdot00165+\cdot00097\right\}} = -0^\circ\cdot8,\ \therefore z' = 53^\circ -$$

$0^\circ\cdot8 = 52^\circ\cdot2.$

Returning to the table: for $z' = 52^\circ\cdot2$ we find $A = 1\cdot24117$; $B = 1\cdot33279$; $\Delta = \cdot00168$; $\delta = \cdot00097$.

$$\therefore z' = \frac{2\cdot8 - \left\{\frac{13}{11}\times1\cdot24117+1\cdot33279\right\}}{10\ \left\{\frac{13}{11}\times\cdot00168+\cdot00097\right\}} = 0^\circ\cdot0125,\ \therefore z'=52^\circ\cdot2$$

$+\,0^\circ\cdot0125 = 52^\circ\cdot2125 = 52^\circ\,12'\,45''.$

As for the fourth pair of pulleys, $\phi = \frac{1}{16}$, $\therefore \frac{1+\phi}{1-\phi} = \frac{17}{15}$, and it is easy to perceive, from the decreasing differences of the angles already calculated, that z will not differ much from 54°. Taking then $z = 54$, the table gives $A = 1\cdot27080$; $B = 1\cdot35027$; $\Delta = \cdot00161$; $\delta = \cdot00096$.

$$\therefore z = \frac{2\cdot3 - \left\{\frac{17}{15}\times1\cdot27080+1\cdot35027\right\}}{10\ \left\{\frac{17}{15}\times\cdot00161+\cdot00096\right\}} = 0^\circ\cdot34,\ \therefore z'=54^\circ\cdot34.$$

For $z' = 54^\circ\cdot3$ the table gives $A = 1\cdot27562$; $B = 1\cdot35316$; $\Delta = \cdot00160$; $\delta = \cdot00097$.

$$\therefore z' = \frac{2\cdot8 - \left\{\frac{17}{15}\times1\cdot27562+1\cdot35316\right\}}{10\cdot\left\{\frac{17}{15}\times\cdot00160+\cdot00097\right\}} = 0^\circ\cdot04101,\ \therefore z'' =$$

$54^\circ\cdot34101 = 54^\circ\,20'\,27''.$

Having now found all the angles, we easily get the radii from the formula $x = \frac{D\sin(\beta+z)}{1-\phi}$ with the help of a table of sines, thus:—

$R' = \frac{30\times\sin 37^\circ\ [illegible]'\,12''}{1-\frac{3}{4}} = 24\cdot5273$; and $r' = \frac{R'}{4} = \frac{24\cdot5273}{4} = 6\cdot1318.$

$R'' = \frac{30\times\sin 48^\circ\,13'\,24''}{1-\frac{7}{8}} = 25\cdot5685$; and $r'' = \frac{25\cdot5685}{8} = 3\cdot1961.$

$R''' = \frac{30\times\sin 52^\circ\,12'\,45''}{1-\frac{1}{12}} = 25\cdot8640$; and $r''' = \frac{25\cdot8640}{12} = 2\cdot1553$

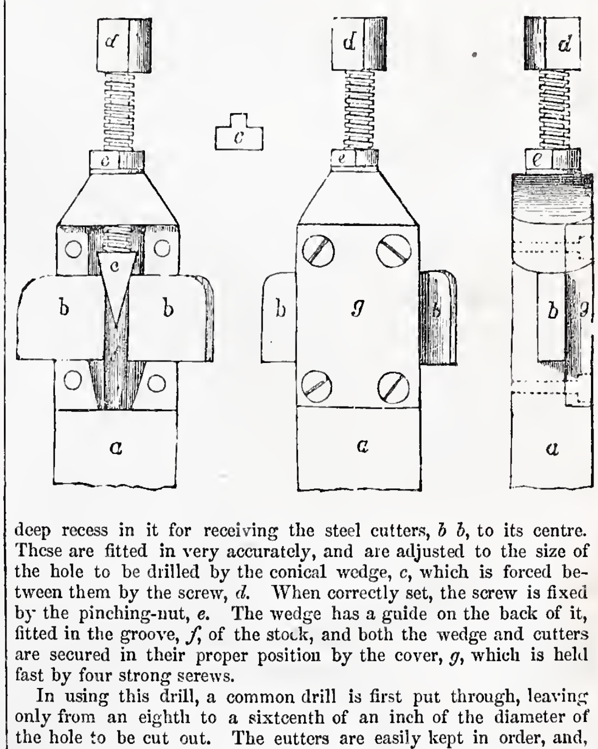
$R'''' = \frac{30\times\sin 54^\circ\,20'\,27''}{1-\frac{1}{16}} = 26\cdot0000$; and $r'''' = \frac{26}{16} = 1\cdot625.$

If we suppose the first pair of pulleys to have been given, in place of the length of the band, we should find by what is stated in some books to be the common rule, viz., to make the sum of the several pairs of diameters equal; 27·2525 and 3·4066 for the radii of the second pair; 28·3007 and 2·3584 for the third, and 28·8556 and 1·8035 for the fourth pair, which aro obviously very erroneous.

In these calculations, it is supposed that the band has no sensible thickness. It is generally said that half the thickness of the band ought to be added to the radius of the pulley to give its real radius; but, perhaps this point is not yet completely ascertained.

GOODISON'S EXPANDING DRILL.

The form of expanding drill represented in the annexed cuts was invented by Mr. Goodison, of Bowling Iron Works, and has been in common use for some years, especially for finishing in the lathe; it is found to be very advantageous where a great variety of sizes of holes is required. Its construction will readily be understood from the drawings, which are half-size of one in use for drilling holes from an inch and a half, to two inches and a quarter diameter. *a*, is the stock, which may be made of any length thought proper. It has a



deep recess in it for receiving the steel cutters, *b b*, to its centre. These are fitted in very accurately, and are adjusted to the size of the hole to be drilled by the conical wedge, *c*, which is forced between them by the screw, *d*. When correctly set, the screw is fixed by the pinching-nut, *e*. The wedge has a guide on the back of it, fitted in the groove, *f*, of the stock, and both the wedge and cutters are secured in their proper position by the cover, *g*, which is held fast by four strong screws.

In using this drill, a common drill is first put through, leaving only from an eighth to a sixteenth of an inch of the diameter of the hole to be cut out. The cutters are easily kept in order, and, with ordinary care, will last for years. They also admit of easy adjustment to any degree of accuracy.

Drills of this kind may of course be made of any size required for the sort of work to be done, and one stock may be provided with two sets of cutters to increase its range of application.

PORTABLE HAND DRILL.

Messrs. Nasmyth, Gaskell, & Co., Manchester.

Much ingenuity has been expended in attempting to devise a really good form of portable hand-drill, "to be driven on the side by a handle attached to the fly-wheel, and the drill spindle to be worked vertically, the pressure for making it descend to be applied at top."

That figured below answers to these conditions, and is the best with which we are acquainted.

Fig. 1.

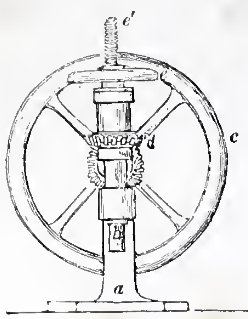


Fig. 2.

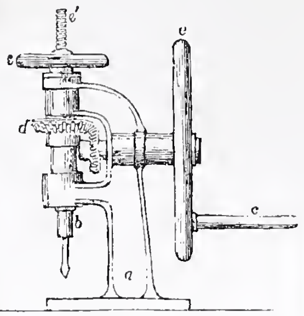


Fig. 1, Elevation.
Fig. 2, Side view.
a, Standard.
b, Drilling spindle.
c, Fly-wheel and handle for working drill.
d, Bevel-wheels for giving motion to the drilling spindle, *b*.
e, Handle for raising or lowering the drill, by means of screw, *d*.

ON THE ECONOMY OF FUEL, AS APPLIED TO THE HEATING OF BUILDINGS.

On the continent, where pit coal is scarce and difficult to be procured, more care is bestowed in the construction of their stoves to economize the fuel than with us. In France, they have a very common stove which combines both utility, economy, and elegance of form, and which has long been in use, especially among the rural portion of the community, both for culinary purposes, and also for the heating of their apartments. As stoves of this kind might be worth introducing into this country also, especially for those districts where peat, turf, or wood, forms a principal part of their fuel, I shall endeavour to give a description of it, as communicated by an intelligent friend, who spent 12 years in various districts of France. These stoves are generally made of cast-iron, and are in the form of an inverted bell, having a small aperture in the bottom, fitted with a sliding register, for the escape of the ashes that fall through the grate, and also to regulate the admission of the air. When required for the purpose of cooking, the cover is removed, and flat rings are put on to suit the size of the vessel to be heated, like the stoves used by confectioners; and to prevent the heat or flame rushing into the vent, it ought to have a loose ring A reaching to within $\frac{1}{2}$ inch of the cover, which would cause the heat to diffuse itself. After their cooking is over, the ashes that fall into the pan beneath are wetted, and then spread over the surface of the glowing charcoal, the tight cover is put on, and the aperture in the bottom almost closed by means of the sliding register. In this state, combustion goes on very slowly, and for 5 or 6 hours this stove will continue to emit a fine glow of heat into the apartment, without any additional fuel. This stove therefore combines both the advantages of Arnott's stove for heating by slow combustion, and also of an open fire when required for cooking, and from the great width at the top, it admits of the use of a girdle, or hot plate, for baking cakes, as well as the gridiron, and culinary utensils of all kinds. However, to adapt this stove for pit coal or coke, it may be proper to line the space for the fuel with cast iron, or fire tile, and to have a tight receptacle for the ashes, and to place the register for the air above it, or just below the grate, as the grosser ashes from the coal might choke up the air passage. These stoves might also be made in the form of a vase, with the drawer for the ashes in the pedestal. Small earthenware stoves of this kind, supported on an iron tripod, are also very common; but as these, like the ancient braziers, have no smoke pipe, and are principally used for cooking in the open air—they do not properly come under our notice. Stoves made of cast-iron are also in general use throughout Holland, Germany, and Poland; but in Russia, Norway and Sweden, where the cold is much more intense, their stoves are constructed of brick and glazed tile, and are therefore very large and massive, because they must have room for the flue to return backward and forward several times, to absorb the heat of the flame that is passing through them. By this means, the brickwork becomes a magazine of heat from the surface of which it is afterwards slowly radiated, at a moderate temperature, and by this means the air in the apartment becomes uniformly heated throughout. In this country, the stove called a cockle has been most generally used. This plan of heating large buildings was considered to be a great improvement over the open fire-grates, from its requiring much less fuel to heat the premises, and the rooms being freed from the dust and ashes of the fires, besides requiring much less attention on the part of the servants. However, from injudicious construction, and the overheating of the cockle, the air frequently became extremely unpleasant and noxious to breathe—in many cases producing giddiness and headaches—and as the cockle sometimes gave way from the intense heat, the flame got into the air passages, and set fire to the buildings. These accidents generally happened when the surface of the iron cockle was too small, in proportion to the area of the building to be heated, or when the air to be heated did not enter in sufficient quantities, or when it was not properly directed upon the surface of the iron to carry

Fig. 1.

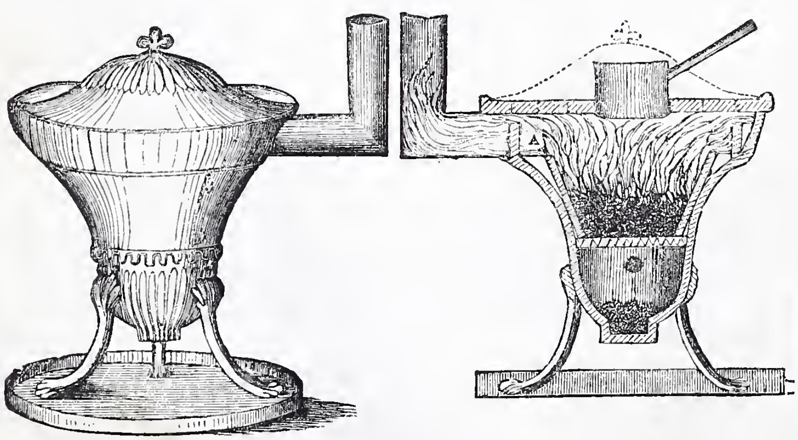
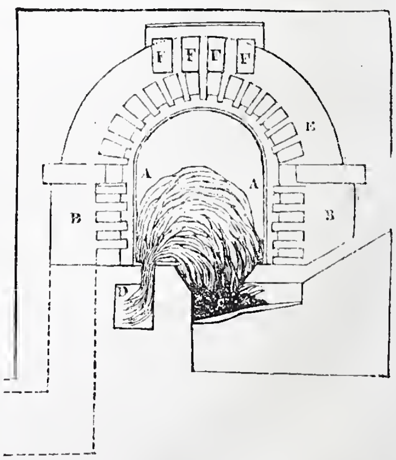


Fig. 2.



off the heat. To remedy these defects, the iron dome or cockle was increased in size, and the air was brought in contact with the surface of the heated metal by means of sheet-iron tubes; and, to increase the supply of air, a long tunnel was formed under ground, terminated with a funnel-mouth, which, by means of a vane, was kept always to the wind.

The annexed figure represents the improved cockle; A A is the iron dome or cockle, constructed either of cast-iron, or thin boiler-

plate, well rivetted. At about 6 inches from the cockle, is a 9 inch brick wall, which is composed of bricks laid with their ends to the cockle. Between every two bricks, is inserted a tube of thin sheet-iron, reaching to within $\frac{3}{4}$ of an inch of the heating surface. The bricks of the second course are laid over the tubes of the first course, and so on alternately. The air tubes are about $2\frac{3}{4}$ inches deep, by 2 inches wide, and 7 inches long, exclusive of the wings cut out of the plate to steady the tubes when built into the brickwork. The bricks for the walls are moulded an inch broader than usual, and about $2\frac{1}{2}$ inches thick; those for the arch must be in the form of a wedge, and moulded to the proper radius, being at their thinnest end 5 inches broad, and $2\frac{1}{2}$ inches thick. B B is the cold air-flue, about 3 feet in height, and 2 feet wide; but the height and width will vary according to the size of stove. The number of tubes ought to be rather greater in the upper half, because the air will increase in bulk as it becomes heated; and as the arch will sink a little, the tubes must always be kept farther off the cockle, than those in the sides. C is the fireplace; the smoke descends through a slit left in the brickwork into the smoke flue D. Great care must be taken that all the joints be perfectly smoke tight, especially where they pass under the cold air flues. E, the hot-air chamber; F the flues to convey the hot air to the various flats or apartments. From the above description, it will be seen that the cockle must be very expensive in the first erection, and very difficult to repair when anything goes wrong, and it also must require a large space for its erection, if the iron cockle is of any considerable size.

Some years since it was found necessary that the large hall of the Andersonian University, in Glasgow, should be better heated, and that the library and apparatus rooms should also be heated at the same time. On consulting a stove-builder, he informed me that the space which the architect had appropriated for this purpose was too narrow to admit a cockle of sufficient size, and that from its being rock below the floor, he could not dig down to form the cold air tunnel. In this dilemma, it occurred to me that a few cast-iron pipes built into a furnace, after the manner of retorts in the ovens of the gas-works, would answer the purpose of a cockle, by simply causing the air to pass through the heated tubes. I accordingly procured 6 cast-iron gas mains of 7 inches diameter, and 9 feet long, cast without the sockets, and had them built up by one of the bricklayers who was working on the premises. By this arrangement, I obtained a heating surface of about 80 superficial feet, being nearly equal to a cockle of 4 feet cube, while the cockle the stove builder was proposing, was only to have been a 3 feet cube, and the smallest possible size of the brick-work was to have been a cube of 6 feet, independent of the tunnel for the cold air; and it was to have cost £40, whereas this one was put up for the following sum :—

6 Cast-iron Mains, ...	£7	10	0
2 Dampers, door, and cover for the fire,	1	0	0
Brickwork, ...	2	0	0
	£10	10	0

This stove being much cheaper in the first erection than the cockle, and having been found to answer the purpose so completely, I sent an account of it to the Editor of the *Edinburgh Philosophical Journal*—(see Vol. VIII. p. 172). Since that period a considerable number have been erected in and about Glasgow. These stoves are well adapted for heating churches, or halls for public meetings, &c.; because they not only heat, but they ventilate at the same time—however, as they seem not to be generally known out of Glasgow, I will give a description of one, and also the sizes of a few of those which have been in operation for several years in Glasgow without requiring any material repair; indeed, as the pipes are never heated to redness, there is nothing to go wrong.

Annexed is a sketch of the heating apparatus, as fitted up for the Female House of Refuge. Fig. 1, is a cross section; and fig. 2, a longitudinal section. In this case, from the peculiar nature of the building, the stove had to be placed outside, but, of course, the arrangement, and the mode of diffusing the heat into the apartments, may be varied to suit the erection to which it is to be applied. The pipes are 8 feet 6 inches long, and 12 inches diameter, and are built in with about 1 foot of inclination,—A, the fire grate; B B, the inclined pipes; C, the end plates $\frac{5}{8}$ inch thick, cast with sockets, 2 inches deep, to form a rust joint round the pipes, which are secured in the plates by pins. The upper ends of the pipes are also wedged, but at the lower end they are allowed to move; and, to prevent the rust on the lower plate adhering to the pipes, the ends are previously coated with paint or pitch. D, the ash-pit door, with a register to regulate the supply of air. The dotted frame, E, shows the door of the furnace which is so hinged as to lie close of itself without a latch, because, when common coal is used, a careless fire-man may cause an explosion which might injure the walls of the furnace were the door fast. F, is the cold-air chamber; G, the hot-air chamber; H, the flue for carrying off the smoke from the furnace. The heated air is admitted into the first flat of the building through the opening, I; the flue, K, carries it into the second, and the flue, L, into the third flat. *a a a a*, are fire-tiles

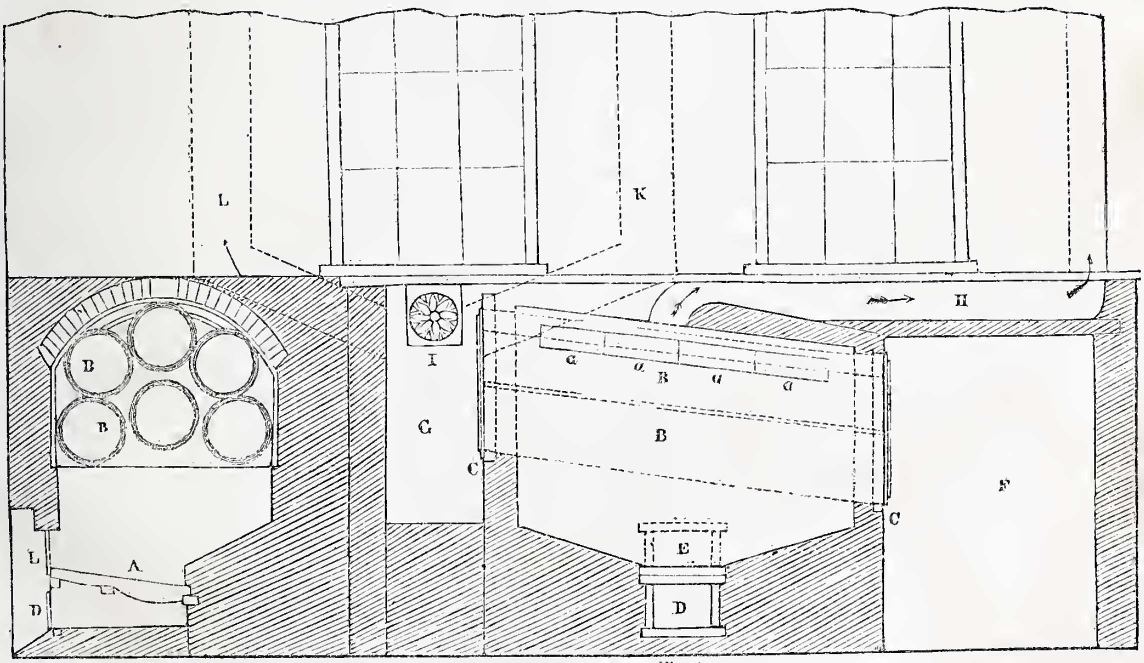


Fig. 1. *Fig.* 2

placed along the upper pipes. In the House of Refuge for Boys, the large stove consists of 10 pipes, 12 inches diameter, which give a heating surface of about 240 superficial feet, or equivalent to an iron coekle of nearly 7 feet cube. The stoves in St Andrew's and St Mary's churches have a heating surface of 220 feet, equal to a coekle of 6 feet 7 inches cube. The Fever Hospital, St Stephen's and Old Monkland churches, have stoves of 140 feet heating surface; Camlachie church has 8 pipes of 12 inches; Bridgeton, 7 of 12 inches; St Luke's, St Mark's, and Bridgegate churches, have 5 pipes of 12 inches, and 1 of 10 inches diameter. It will be unnecessary to enumerate any more, as these, with the sketch, will be sufficient data for any stove-builder to fit them up by.

When a building, containing a number of apartments, required to be heated, this could not be so easily accomplished, under the hot-air system, unless it had been previously constructed with proper flues to conduct the air to the various chambers. On this account, heating by steam was resorted to, because the steam-pipes were much easier put up, or concealed in a building, than hot-air flues; and, as it was also free from danger of fire, while it produced a very agreeable heat, and was totally free from smell or dust. The difficulty, however, of keeping the steam-pipes perfectly tight, and the trouble and expense of attending on a small boiler, and the risk from carelessness, or of not keeping up the steam—because the instant the supply fails, condensation takes place, and the pipes become filled with air; and, even after the steam is again got up, a considerable time must elapse before the air can be expelled, and the pipes again filled with the steam—have rendered all attempts, to heat churches or private buildings, by this means, a complete failure; but in cotton, or other factories, where a regular supply of steam, from the boiler of the engine, can at all times be obtained, this manner of heating answers admirably. However, a much steadier and better method of distributing heat, throughout the various apartments of a building, has superseded the use of steam in private buildings altogether, namely, by the circulation of hot water. This principle was first introduced for the purpose of heating hot-houses, conservatories, &c., and being found to answer the purpose so well, it was soon after applied to the heating of buildings. This apparatus eonsists of a vessel resembling a small boiler, and built into a furnace in the same manner, only the flues are carried over the top also. From the top of this vessel, a pipe of from four to six inches diameter ascends and enters the building to be heated,—here it is generally concealed behind the base moulding, which in this case is commonly formed of light castings of open fretw rk, to allow the escape of the heated air. In this manner, the pipe is conducted from one apartment to another, until it reaches the highest point where the heat is wanted; it then begins to descend by the most direct course, until it enters the heating vessel near the bottom, where it again becomes heated. The principle of its action is the difference in the specific gravity of the two columns of water, the water in the vessel being expanded by the heat, becomes specifieally lighter than the water that has parted with its heat in its passage along the pipe; it therefore tends to ascend by the pipe in the top of the heating vessel, while the other end of the column, becoming specifically heavier, tends to descend to the lowest point or bottom of the heating vessel. This difference in the gravity of the two columns of water is sufficient to cause a eontinual circulation of the hot water throughout the whole length of the pipe, however, as pipes of four or five inehes diameter are in many cases diffieult to be concealed, or even to be got in at all, another modification of this principle was introduced by Mr Perkins. His apparatus eonsists of a series of small wrought-iron pipes, so joined together as to form a continuous tube; the two ends being united together, and being only one inch in diameter, they are easily bent to suit the form of the building, or eoiled up to inerease the surface, where a greater degree of heat is wanted; and to make up for the want of radiating surface, he heats the water to a mueh higher temperature; but as this ean only be done under an enormous pressure, which no ordinary vessel eould withstand, a part of the pipe itself is eoiled up and placed in the furnaee. This is a very elegant method of heating; and, from the facility of bending or eoncealing the pipe, it ean be applied in almost any situation; but it has its disadvantages also. From the enormous pressure in the pipes, it is impossible to shorten the circuit by putting either valves or stop-cocks in them, so as to shut off part of the rooms when not wanted, as is done in the low pressure system, to save fuel. In this, if only two or three apartments require to be heated, fuel to heat the whole rooms in the building must be consumed, or separate apparatus must be erected to heat different parts of the building. It has also been charged with setting fire to buildings, from wood or inflammable substances that happened to be in contact, or laid upon the pipes. This last, however, can easily be guarded against, and we surely never would abandon fires in our rooms, solely because children or females' clothes are at times set in a blaze by their approaching too near the fire. From the small quantity of water in the pipes, it also requires more care and attention than the low pressure to keep up a uniform temperature. On this account, the low pressure is much better suited for hot-houses or any situation where a steady temperature is required, or where a careful and steady person cannot always be at hand to attend to it. In hot-houses they generally have a large cistern of water at the highest point, the ascending pipe enters it near the top, and the descending pipe leaves it at the bottom. By this means they have a large mass of hot water, both in the heating vessel, the pipes, and the cistern, which keeps up the temperature, even although the fire may be neglected through the night; and, by throwing open the top of the cistern, they can produce a moist atmosphere at pleasure by the evaporation from the surface of the hot water. Where they have no cistern, metal boxes are laid upon the pipes, which they fill with water when neeessary.

I shall now conclude with a few general observations. The French stove, with a few improvements, might be rendered a very useful and an economical stove, especially for cottages or small country houses. Their form also must render them very easily moulded; and if care were taken to have the upper edge of the lid neatly fitted, or even turned, there would be no necessity to cover up the fuel with wet ashes, as is done in Franee; and, if an explosion were to take place, (as sometimes happens with Arnott's stove,) it would only lift up the lid a little; however, the air that would pass up between the fire-tile lining and the outer case would effectually prevent this. Indeed, in all cast-iron stoves, the chamber for the fuel ought to be lined with fire-tile, both to prevent the air from being deteriorated, and also from being too highly rarefied; for, the larger the surface of the heating medium, and the nearer it approaches to the temperature required, the more uniform and agreeable will the heat of the apartment be, while, by a small surface, with a high temperature, the air must be so much rarefied that it will instantly ascend to the ceiling, by which means the upper part of the room will be rendered uncomfortably hot, while the lower part will remain comparatively cold; and in this consists the superiority of the brick stoves of Russia in diffusing so agreeable a temperature; hence the propriety of a large cockle, or other heating surface, with a moderate temperature, and introducing the heat by means of a large quantity of air moderately heated, in preference to a smaller quantity at a higher temperature. Thus, a current of air at the temperature of 60°, entering an apartment at the rate of 7 cubic feet per second, will mix and diffuse the heat much better through the air in the room, than 2 feet heated to 212°, or than 1 foot per second heated to 424°, because the latter, from the increased levity, would flow up to the ceiling at once; henee, also, the propriety of introducing the air at as low a point as can be got. In churches, it ought always to be admitted below the gallery, if possible, in the first place; and for the same reason both steam and hot-water pipes ought to be introduced as near to the floor as possible. With regard to the radiating powers of the steam and hot-water pipes, this depends upon the temperature of the pipe, and the air of the room. In eotton factories, they find that 1 superficial foot of steam-pipe will heat from 160 to 180 cubic feet of space to about 85° in winter. With hot water, upon the low-pressure principle, as the water is always below the boiling point in the pipes, rather more surface will be required than for steam, while the hot-water pipes, on the high-pressure plan, being so much hotter than low-pressure steam, $\frac{1}{2}$ or $\frac{1}{3}$ of a foot will radiate as much heat as a steam pipe, with the low-pressure steam, but this entirely depends upon the temperature of the water in the pipes. From steam-pipes supplied from an engine-boiler, the temperature will be pretty uniform, but the temperature from the hot-water pipes will vary with the state of the fire, and these changes will also be more apparent in the high-pressure than in the low, from the smaller quantity of water and materials in the former to retain the heat.

John Hart.

FARADAY'S SPECULATION ON MATTER AND ELECTRIC CONDUCTION EXAMINED.

ARTICLE III.

20. PETIT and Dulong's researches render it probable that the *atoms* (or weights indicated by their equivalent numbers) of simple substances all have the same capacities for heat; hence the specific heat of an elementary substance, multiplied into the weight of its prime equivalent, should always give the same product. The truth of this law has been confirmed by Regnault; but, without entering into such hypothetical investigations, we may observe that gold, platinum, lead, and mercury, appear to possess the same thermal capacity, or nearly so; of these, gold, whose specific gravity is 19·25, stands highest as a conductor of heat; but platinum, with a *higher* density, is one of the worst conductors. The cause of this may be explained by the fact, that as the same increase of temperature produces in each metal a greater or less degree of expansion, that metal whose constituent particles are naturally most contiguous, and which expands the least with a certain amount of heat, must offer the greatest degree of resistance to the passage of heat; for the reason, that if heat cannot enter a metal without increasing its bulk, *that* metal—the internal arrangement of whose particles is such as to offer great resistance to the separation of those particles—must naturally oppose the easy transmission through its mass, of any principle which requires a certain amount of space for its presence; consequently, platinum, whose particles are more approximated and spaces less than those of any other metal, excepting iridium, and which requires an enormous amount of heat, far surpassing that of other metals, to break down the cohesion of its molecules, must oppose the passage of a quantity of heat, which, however inadequate to separate its particles ever so little, still demands increase of space for its easy transmission. Therefore, as we find that in the case of other metals, as well as that of platinum, facility or difficulty of electrical conduction is always accompanied by facility or difficulty in conduction of heat: it will not appear an extraordinary conclusion that platinum should, for this reason, resist conduction of electricity.

21. It is not to be understood that we mean to attribute to the actual amount of heat residing within this metal, the opposition to electrical transmission, but rather to the difficulty which this quantity finds in temporarily expanding the metal, so as to admit of that arrangement of the particles, or other peculiar condition, which conduces to the passage of the electric current, for other metals possess a larger, or, like gold, an equal capacity for heat, and yet admit of its easy propagation; but the density of these metals is less than that of platinum, therefore their spaces are greater; and for a given amount of heat, their dilatation is greater, and a much smaller amount of heat is requisite for that purpose; therefore the resistance being less, there is less difficulty in the establishment of that molecular condition which facilitates the progress of the electric current.

22. Lead is another metal having the same thermal capacity, or nearly so, while its density is little more than half; but its resistance to the passage of electricity, and also to that of heat, is more than double the amount of platinum. In this instance, it would appear that the metal is a bad conductor, because the electrical condition of its particles is highly positive, and because those particles are so constituted and arranged, that the passage of the fluid through its mass is impeded.

23. In mercury the electrical conducting power is not an eighth part of that of platinum; but, like platinum, its electrical condition is highly negative, and its conducting power for heat still lower; but its density ranks next to that of platinum and gold. In this case, therefore, we can only attribute its inferior conducting powers for electricity and heat, to its *fluid* condition, whereby an arrangement of its particles obtains which does not fulfil the conditions requisite for easy conduction.

24. It thus becomes apparent, that in all cases where those qualities which are believed to support or impede electrical or thermal conduction, are not attended with corresponding results, there may be found in the molecular constitution of the metal so forming an exception, some peculiar character or property which will account for that exception. We may hence draw the conclusions, that in all bodies which are conductors of electricity and heat, there may be found a peculiar disposition of the molecules or particles, which will afford greater or less facility to the passage of both—that where that peculiar constitution does *not* exist in any degree, the power of conduction is *non-existent*—that where it *does* exist to a limited extent, it may be improved or deteriorated by mechanical or other artificial means—that even in certain cases, where it does not naturally exist, the same artificial means may, by production of a new internal arrangement of particles, produce it—and furthermore, that a relation will be found to subsist between the varying degrees of conduction and the proportions which the molecular spaces and those existing between the particles or atoms constituting the molecules, taken in connection with the ethereal and thermal principles occupying those spaces, bear respectively to one another.

25. We are not here about to raise the question, whether the ether which we have assumed, not without good grounds, to occupy space, may not consist of heat and electricity—two antagonistic principles, combined;—but under certain circumstances of their connection with matter, capable of separation and of individual action. We would merely observe, that such a compound ether would fully answer all the objects contemplated in our previous arguments, and besides, satisfactorily elucidate many of nature's most secret operations. Were we inclined to speculate, we might write much upon this seductive subject; but our object has been, and is, by grounding our arguments and conclusions as much as practicable, upon the results of every-day experience, and upon well-known properties and phenomena of the various forms of nature, to demonstrate the inutility, and more than that, the absolute injury to the progress of knowledge, of such wildly speculative notions as those of Boscovich and his modern disciples—notions which may be taken to imply a doubt of the power of the Supreme Being to create, on the one hand, anything *more material* than *central points;* or, on the other hand, anything less material or less ponderable than gaseous hydrogen, as if the power that created the latter could not likewise create an element one million times more attenuated and less ponderable, but still analogous to proper material forms in all its natural attributes; for, if they do not doubt this power, why seek to attribute the more secret and less intelligible phenomena of nature to certain mystical modes of operation, so opposed in every way to our conceptions of those modes of operation manifested in everything tangible and perceptible around us.

26. It must appear from the preceding considerations, that Dr Faraday's arguments in proof of the non-existence of space, are, to say the least, extremely inapposite, and that his premises do not warrant his conclusions. He places shell-lac, a *compound unmetallic* substance, in comparison with potassium, a *simple* inorganic *metallic* body; and because he finds that the former is an insulator and the latter a conductor, while space between the constituent particles is common to both, he draws the conclusion that since space (meaning thereby *empty* space) cannot be a conductor in one case and an insulator in another, but must be either a conductor in *every* case, or an insulator in *every* case—which it is not—space cannot exist at all; therefore, that all matter must be continuous, but that it can *only* be so upon the assumption of Boscovich's mathematical points and centres of force, thus denying the possibility of the interstitial spaces of bodies being occupied by a subtile fluid or fluids, as much less ponderable than hydrogen, as hydrogen is less ponderable than

platinum, but still essentially material and preserving the continuity of matter. All in the world that he has really demonstrated is, that space cannot be a conductor in potassium and an insulator in shell-lac; but surely such a demonstration does not justify his subsequent inferences, nor afford the slightest ground for his speculations respecting the nature of matter. We have already proved, upon various grounds, that the dimensions of the spaces, and therefore the spaces themselves, have no effect one way or the other, upon conduction or insulation; and we have thus shown that Dr Faraday should not have grounded his arguments upon the supposed existence of *empty* spaces exercising *opposite* influences. We have also demonstrated, that the constitution of the particles of substances, as well as their arrangement in the mass—their peculiar electrical condition—their capacity for heat—expansive properties, and thermal conducting powers, are quite sufficient to account for the discrepancies of electric conduction in the various forms of matter; and that if space exercises any influence, it is only as *occupied* space, taken in connection with some or all of the above conditions.

27. These important considerations Dr Faraday appears to have totally neglected; else why have introduced the doctrine of central forces? or why not have seen in the constitution and arrangement of the compound molecules of shell-lac, as well as its peculiar nature, a sufficient reason for its *insulating* property; and in the arrangement of the more simple particles of potassium, and its peculiar attributes, a satisfactory reason for its conducting power? Why not have perceived that if gold was superior in conducting properties to platinum, their molecular arrangement was *distinct*—their density *distinct*—their conducting power for heat *distinct*—and last not least, their expansive properties *distinct;* that of gold for a given amount of heat, being nearly double that of platinum. Why esteem it singular that oxide of potassium should contain *more* potassium in a given bulk, than the element itself, and that the *former* should not be in consequence a better conductor than the *latter?* Why not have borne in mind, that oxide of potassium being a compound body, its molecules must present an aggregation in *potassa,* widely differing from that of the simple and more separated particles in *potassium;* while those of potassium, and also of potassa, must differ as widely from the more complex molecular arrangements in shell-lac; and that the different relations of each to specific heat, to specific electricity, to conduction of heat, and to expansive power, are quite sufficient to account for the distinction in electrical conducting properties between potassa and potassium, and potassa and shell-lac.

28. Instead, therefore, of propounding metaphysical subtleties, because the assumed *empty* space of the *atomists,* existing between the particles of masses of matter, and believed to influence electrical conduction, cannot be admitted to oppose conduction in one case and promote it in another; let us abandon this foolish notion of *empty* interstitial spaces, and while we fully recognise space as existing between the particles and atoms of bodies, let us believe that there is nothing like a *void,* but that such intervals are occupied by a material principle or principles, *not imponderable,* but too light to be weighed by our *still* imperfect instruments, and so subtile as to possess power of penetration where grosser forms of matter cannot enter. Let us even go the length of believing in the existence of one principle peculiar to the *smaller* spaces between the atoms uniting to form a *particle,* and another peculiar to the *larger* intervals between the particles uniting to constitute a mass In so doing, we do not go beyond the bounds of probability, and only reason from the powers and modes of action of *known* elements. to analogous powers and modes of action of others yet *unknown;* we preserve the same system of operation in nature's most secret workings as in her most apparent ones; and we thus establish a rational continuity in creation, too firm to be broken by the theories, however ingenious, of clever metaphysicians. Finally, building upon so sure a foundation, we shall be able to turn to good account the knowledge we are daily acquiring with respect to the wonderful properties of light and heat, the nature of electric and magnetic action, and the molecular arrangements in crystalline, organic, and other forms of matter.

29. We may now properly close this chapter with a few additional observations and examples, in corroboration of our views respecting the existence of spaces of different dimensions within the same body—of particles of different forms and sizes in the same substance—and of the influence of diversity of molecular aggregation upon the conducting powers of matter. It would appear that the term ATOM, in the sense in which it is applied by many distinguished philosophers, cannot be recognised in the present state of our knowledge of molecular phenomena. So long as it is restricted to those groups which combine *chemically,* and which *cannot be separated* by *chemical* means, the term will apply. Such atoms, or rather atomic groups, when weighed against each other, produce what we designate equivalent numbers, and the rules of definite combination are founded upon their union; but when these atomic groups are acted upon by *physical* forces, they may then be broken up and each group formed into different *minor* groups; or a number of them may be united or combined into one *larger* group, distinguished by certain relations to heat and pressure; but no longer the atoms engaged in *chemical* combinations. Thus, as observed by Professor Kane, that group which is acted on by heat, when a gas expands, occupies only *half* the space in muriatic acid that the *chemical* group occupies; but in gaseous sulphur, it occupies *three times* the space of the chemical atom. In gaseous oxygen, arsenic, and phosphorus, the *mechanical* atom is of the same volume; but the *chemical* atom consists of only *half* the volume that is occupied by each, in iodine, hydrogen, and chlorine.

30. Again, although it is known that of the metals in the table (page 262,) gold, silver, copper, platinum, lead, and mercury, crystallize according to the *regular* system, the assumption of such forms by these metals may arise from circumstances which are known to confer *external* cubical and other figures upon other bodies, while their *internal* arrangement and structure are much more complex, and widely different. Copper and gold, therefore, which crystallize in cubes, and lead, silver, and zinc, which crystallize in octohedrons, may belong to either the *square* or *right-prismatic* systems. Copper, gold, and silver, which are all good conductors of electricity and heat, may therefore crystallize according to *one* system; and lead and zinc, and certain other metals, which are bad conductors, according to a *different* system. The dimorphism, or assumption by the *same* body of incompatible crystalline forms, is a further proof that *chemical* constitution does not *determine* the molecular structure, although it may to a certain extent and in certain cases *influence* it. Even in solid bodies a difference in molecular structure may be very easily produced: thus, the compression of a plate of glass by means of a screw, causes it to assume a double refracting structure, which arises of necessity from increase of density in the compressed portions. But the same effect may be produced by the sudden cooling of a red-hot plate of glass; although in the latter case, the density is diminished in place of being increased. We therefore see that *one chemical* substance may exist in *two* different molecular conditions; and there is no difficulty in understanding that this *same* chemical substance may be a conductor of electricity in *one* molecular condition, and an insulator of it in *another.* But this is not all, for we know that one chemical substance may not only exist as above, in two different molecular conditions, but that in these two forms, the *elements* and *proportions continuing the same,* it may constitute *two distinct chemical substances.* It is thus with olefiant gas, which consists of one equivalent of carbon and one of hydrogen; but a *solid* body, paraffine, consisting of the same elements in the like proportions, is also obtainable—the *gas* being remarkable for the number of compounds which it originates; while the *solid* is totally indifferent to combination, and capable of resisting the most

powerful agents; proving that the molecules are not alone differently arranged, but that they possess themselves a different internal constitution. The elements of the molecules or atomic group, are differently arranged, and thus produce difference of properties; and the molecules themselves being again arranged or grouped differently, create the difference in *physical* properties and states of aggregation.

28. So much for the difference between the *chemical* and *physical* molecular constitution of bodies. In the case of glass, a compound body, we have seen that pressure or sudden cooling has the effect of altering its internal molecular arrangement and giving it different properties. The same, and *other* causes, will however produce like effects in simple bodies, such as the metals. Let one instance suffice: if we take a piece of soft copper or silver wire, and examine its conducting power for electricity—and subsequently increase its length by stretching—we shall find that in place of being soft and tough, it becomes hard and brittle; and on again testing its conducting powers, as well for heat as electricity, we shall perceive both considerably diminished;—all owing to the molecular alteration which has been produced by straining. For this reason, we find that a wire which has been once wound round an electro-magnet, if removed and again wound upon the same metal, will not develop the same power as before. When therefore we perceive the most extraordinary and most opposite properties and effects developed by such apparently trivial changes, we can experience no great difficulty in satisfying ourselves as to the causes of non-conduction in *shell-lac* and of conduction in *potassium*, of the slight resistance to conduction of gold and silver and copper, and of the great resistance of platinum and zinc and lead. We can comprehend that *physical* molecular constitution may be *different,* while *chemical* molecular constitution is the *same;* and thus reconcile to our understandings the causes of the various dissimilar properties and attributes of substances, without the aid of the *impenetrable* particles, and *empty* spaces of the atomic theorists, or of the unsubstantial *central points* of the *immaterial* philosophers.

NATURAL PHILOSOPHY AND CHEMISTRY.

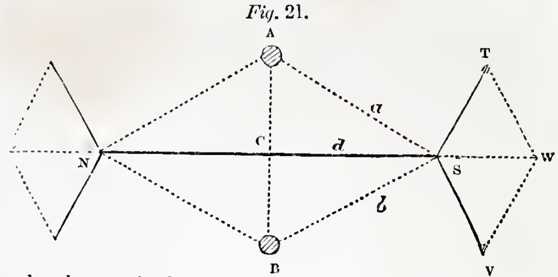
CHAPTER XXVI.

ON THE PRESENT STATE OF ELECTRO-MAGNETISM.

63. In considering the subject of electro-magnetic rotations in the last chapter, the influence of ascending or descending currents upon *one pole only* of a magnet, was chiefly regarded; but ascending and descending currents have been shown, upon the principles previously stated, to exercise a joint and similar influence in some cases upon *one* pole, and in others, upon *both* poles of a magnet; and conversely, *both* poles of a magnet upon an ascending or descending current of a conducting wire. This united force of currents moving in contrary directions, was cursorily instanced in paragraph 32, in the simplest form of the galvanometer; and the joint influence of the contrary poles of a magnet may be demonstrated by the suspension of a wire conducting an electric current, between the poles of a magnet, of the horse-shoe form, and dipping into a trough placed between these poles containing mercury, and thus connected with the battery; the wire will be impelled backwards or forwards between the limbs of the magnet, according as the current ascends or descends, until it leaves the mercury, when its weight brings it back, and causes renewed contact.

64. In the case of a magnet influenced by a current moving in contrary directions; the force of deviation of each pole from the plane in which the conducting wire is situated, in a direction at right angles to that plane, will be found to be directly as the intensity of that current, (assuming it to be *equal* in both directions,) and directly as the interval between the two portions of wire conveying the current, and inversely as the square of the distance of each pole from the wire. For example, let us suppose A and B to be sections of two wires perpendicular to the plane of the paper, and parallel to

Fig. 21.



each other, as in fig. 21; and the interval between them to be represented by the line A B, of which C is the centre; let C be also the central point of a magnet N S, equidistant from both wires, and whose poles are deflected to a certain angle on the right and left of the plane of the wires. In this instance we may suppose the line C S to be the distance of the pole S from the plane, and to be perpendicular to that plane. In this state of things, the intensity of the tangential force exerted on the pole S by the wire A, is inversely as the distance A S, and acts in the direction S T perpendicular to A S. In the same way, the wire B influences the pole S in the direction S V, with a force equal to S T; if then, we assume these forces to be represented by the lines S V and S T, the resultant force will be found in the diagonal S W of a parallelogram, having these lines for two of its sides. But as the line C S will vary in length, according to the amount of deflection of the magnet from the plane of the wires, the lines S T and S V, representing the tangential forces, will vary inversely as the distances A S and B S; in other words, the force composed of the united action of the wires A and B, which urges S in the direction of the diagonal S W away from their plane, varies *inversely* as the square of the distance of S from either of the wires, and *directly* as the length of the interval A B between the wires. The forces exerted upon the other pole N are represented in the figure, and may be explained similarly.

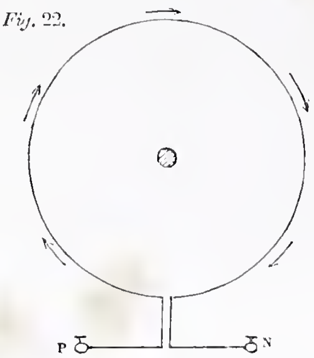
65. Where the magnet is compelled to move round a fixed axis, in a plane perpendicular to that of the wires, we shall have to resolve the force previously found into a force acting in the direction of a tangent to the circle in which the poles revolve; that is, we shall have to reduce it according to the proportion the radius bears to the cosine of the angle formed by the magnet with the plane of the wires.

66. In such cases as that represented in fig. 23, where the wires, in place of extending horizontally, encompass the magnet, those parts of the conducting wire connecting the horizontal portions, exert a certain influence, which requires to be considered in calculating the amount of effect; but it will appear from what has been previously stated, that these connecting portions agree with the other parts in influencing the magnetic movements in the same direction; for which reason, if the encompassing wire be bent into a circular form, and the pole of a magnet be placed in the centre of the circle, or in a line forming its axis, that pole will be urged in the same direction from every part of the circumference during the transmission of the current along the circular wire.

67. If the extremities of the wire bent into a circular form, be brought nearly into contact, so as to form an almost perfect circle, as in the annexed figure 22, and the extremity P be connected with the positive electrode, the current will appear to a spectator facing the circle to pass along the wire in the direction of the hands of a watch, but if viewed on the *remote* side, it will appear to move in the contrary direction. If then, the north pole of a magnet be placed in front of its centre, it will move from the front towards the centre of that circle; and if the circle were at liberty to move, it would advance towards the pole, thus exhibiting an attractive force; but if, on the other hand, the south pole were placed in the same position, that is, in *front* of the circle, it would retreat from the centre, and similarly, the circle from it, thus giving the appearance of mutual repulsion. The contrary effects would take

place if the poles were placed before the centre on the *remote* side of the circle, that is, the north pole, which before was attracted, would now be repelled; and the south pole, which in the former case was repelled, would now be attracted.

Fig. 22.



68. It follows from the position of the magnetic poles in the axis of the circular conducting wire, that every portion of the current exercises an equal force upon the pole of a magnet in the same position, which force varies inversely as the square of the distance, and that the intensity of the attraction or repulsion of the united forces upon either pole of a magnet, varies directly as the square of the diameter of the current, and inversely as the third power of the distance of that pole from the wire conducting the current.

69. From the preceding considerations it becomes apparent, that the two sides of the plane of the circular conducting wire act as the poles of a magnet—one side exhibiting *northern* polarity to the *south* pole of a magnet facing its centre, and the other side *southern* polarity to the *north* pole of a magnet facing that side; it therefore follows, that this magnetic force may be very greatly augmented by placing a number of circular conducting wires one within the other, in the same place. This has been accomplished in practice, by the formation of the wire into a flat spiral, the planes of whose circles very nearly coincide; and still more conveniently, by winding the wire on a cylindrical surface, in the form of a cork-screw or helix, the several turns of which may be regarded as circles separated slightly from each other, whose planes are nearly parallel, and which have the same axis. This latter arrangement exhibits many singular properties, as well with respect to its *internal* as its *external* action.

70. The compound influence exerted by the helical arrangement, has the effect of urging the north pole of a magnet placed in its axis in the *same* direction, in the line of the axis, and the south pole in the *opposite* direction. This influence is governed by the direction of the current in relation to the axis of the helix, and also by the direction in which the thread of the screw turns. If the thread turns in the direction of the hands of a watch, that is, downwards from right to left, the helix is called *right-handed;* if in the contrary direction, left-handed; and the north pole of a magnet lying within a horizontal helix, in the line of its axis, will be determined either to the right or left of a spectator facing the side of the helix, according to the direction in which the current is transmitted: in other words, the north pole of a magnet will be found on the right, and the south pole on the left; if the current be sent through the *right*-handed helix, from left to right; and in the *left*-handed helix, from right to left.

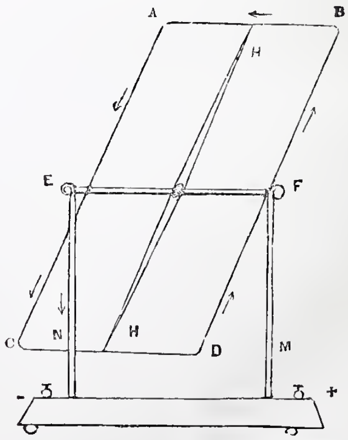
71. When the magnet is so placed within the helix that its middle point coincides with the middle point of the axis of the helix, the opposing forces which urge both poles in different directions, and which arise from each coil, will be found to balance one another, and in consequence, the needle is in equilibrium; but if the magnet be urged nearer one end of the helix, the opposing forces will exert a greater influence upon the pole which is nearest the middle point of the axis, not only because they are nearer, but because their action is less oblique. The effect of this greater force will be to draw back the magnet to its former central position, and thus restore the equilibrium; this action, however, only occurs when the *south* pole of the magnet is in *front* of the current, as explained in paragraph 67, for in this case, whatever be the disturbance, the centres of the current and magnet will repel each other; but if the *north* pole occupy that position, any derangement will be attended by unequal attraction of those centres, and the equilibrium will not be restored. Therefore, in the former case, there will be *stable*, and in the latter case *instable* equilibrium.

72. If a helix be suspended by a thread attached to its centre, so as to be capable of horizontal movement, and if at the same time it be connected with a battery, as soon as the current passes it will be found to place itself on the magnetic meridian, that end of the helix, if *right*-handed, at which the current *enters* assuming the magnetic properties of a *south* pole, and the end at which it departs, those of a *north;* but if the helix be *left*-handed, these polar properties will be reversed.

73. The preceding example demonstrates, perhaps as clearly as any other, the influence of terrestrial magnetism upon voltaic currents. The simplest contrivance for this purpose, consists of the wire bent into a circular form, as described in fig. 22, with this difference, that in this case, the extremities of the circular wire are connected with a small voltaic arrangement placed in a floating vessel, by which means the ring is capable of turning itself into any vertical position; but in such an arrangement, the effect is not so intelligible, inasmuch as the conducting wire consists of only one coil, and in consequence, the plane of the ring will appear at right angles to the plane of the magnetic meridian, and it will be the sides of that plane which will face north and south; when however, this ring is multiplied, becoming a series of rings in the form of the helix, the polar direction then becomes apparent; for the axis of the several convolutions then turns north and south, assuming in every respect the appearance of a natural magnet or a magnetic needle; and the currents passing transversely, or in planes at right angles to the planes of the magnetic meridian and line of direction, are represented by the coils of the helix passing round their axis.

74. Neither of the above arrangements is, however, capable of illustrating the magnetic dip; for, as the line of force of terrestrial magnetism, in our latitude, cannot be parallel to the axis of the earth, in consequence of the unequal influence of the terrestrial poles, but is inclined at an angle of about seventy degrees to the horizon; the action of that force upon a voltaic conducting wire, so bent as to form a circle or square, or any other figure terminating where it commenced, will be to arrange it in a position perpendicular to that of the dipping needle, or perpendicular to the direction of the earth's magnetic force. In order therefore to meet this diffi-

Fig. 23.



culty, Ampère constructed an apparatus similar to that in the annexed figure, in which A B C D is a rectangle of stout cop-

per wire, having its commencement and termination at F, the commencement being connected with the metal pillar M, and through it with one end of the battery, and its termination being carried across from F to E, and through the pillar N to the other pole. The rectangle works upon two pivots, E F, which being horizontal, the motion of the rectangle will be vertical. If therefore the line connecting the pivots be placed at right angles to the magnetic meridian, and a current sent in the direction of the arrows, the rectangle will immediately oscillate, and presently come to rest in a plane perpendicular to the line of the dip; that is, in the plane of the magnetic equator. The central line H H parallel to the sides of the rectangle represents a light piece of wood, for the purpose of supporting the wire forming the rectangle.

75. We thus see that the influence of the earth's magnetism upon *bent* wires conducting an electric current, is perfectly analogous to that exerted upon magnetic needles, but it remains to be shown whether a *straight* conducting wire is influenced by the earth in a similar manner to what it would be by a similar pole of a contiguous magnet. In considering the effects to be expected from the operation of terrestrial magnetism on such a wire, which we know to be the same as that exerted by a south magnetic pole in the direction of the dip, we shall be able to deduce from the laws previously detailed, that the electro-magnetic force, being tangential, must act at right angles to that direction; in other words, to that of the line connecting the wire with the magnetic pole; and we shall find that the influence of this force upon a current either ascending or descending in the line of the dip, is reduced to nothing, and that its greatest intensity must be exerted upon a current moving perpendicularly to that line. But, in order that a straight line may occupy that direction, it must be located in the plane of the magnetic equator. This therefore, is the position in which the earth exercises the fullest magnetic influence upon the wire; and that influence urges it to move in a line parallel to itself, and at the same time perpendicular to the direction of the dip; and upon the course of the current passing along it, will depend the direction in which it will move in the plane of the magnetic equator. For instance, if we place the wire in a horizontal position, and in the direction of the magnetic east and west, and send through it a current in the direction from west to east; the earth's influence, which is that of a *south* pole, will in that case incline the wire to move towards the north, that is, to *ascend* in the plane of the magnetic equator, which plane, we are aware, has a southerly dip, with an inclination towards the horizon of about twenty degrees, which is equal to the complement of the dip.

76. If the direction of the conducting wire in the magnetic plane be from north to south, and if the electric current be sent in the same direction, the wire will incline to move towards the *east*, still keeping in the same plane, and maintaining parallelism to itself; but if the direction of the current be from south to north, the wire will tend to move from east to west. Of course, these observations have reference to what occurs in the *northern* magnetic hemisphere, and those parts where the dip is about 70 degrees.

ON THE SUPPOSED INFLUENCE OF THE MOON UPON THE WEATHER.

By Walter Crum, F.R.S.

[Read before the Glasgow Philosophical Society.]

There is no more common belief, even among those who make accurate observations on other subjects, than that changes of the weather are more decided, and occur more frequently at changes of the moon than at any other period of the month. A similar influence is very generally ascribed to the full moon; and not a few look for changes at the commencement of every quarter.

I had abundant opportunity of observing the firmness with which this opinion is held by a class of men who are placed in circumstances that may be thought the most favourable for testing its correctness. In December, 1820, I sailed in a Maltese vessel from Valletta to Marseilles, and took six weeks to perform what is usually done in ten days. I soon became desirous to gather opinions of the weather, and found them to be formed entirely on the phases of the moon. Every new quarter was to bring a favourable wind, and although we were repeatedly disappointed, the next quarter was still anxiously looked forward to for relief. During that voyage my faith in the moon, if I ever had any, was thoroughly shaken, and I afterwards became desirous to procure facts which would enable me to form an accurate opinion on the subject. I was not a little pleased, therefore, to meet, in the following year, with a paper by Professor Olbers, of Bremen, "On the Influence of the Moon upon the Seasons;" confirming most satisfactorily the views I had formed upon slighter examination.

As on all subjects where uncertainty prevails, and where men are guided more by imagination than by fact, there is here the greatest variety of opinion. In some of our almanacks minute directions have long been given for predicting the weather for the succeeding half month, from the hour of the day or night at which the moon enters the first or the third quarter; and I know that they obtain very general credit, their antiquity forming an important argument in their favour. For instance, if we have new or full moon at mid-day, we may expect much rain in summer, and rain and snow in winter. If at midnight, the weather will be fair in summer, and fair and frosty in winter; and so on, for every two hours in the twenty-four. These predictions, or rather rules for predicting, we are assured have stood the test of half a century; but if, as is said, they were drawn up by Dr Samuel Clarke, from his own experience, they must have existed at least a hundred and twenty years.

I trust that the great prevalence of such impressions will excuse me for calling attention to it; and if the statements I have collected are already familiar, it is still to be borne in mind, that although there are certainly more dangerous errors, yet it cannot be doubted that the habit of holding loose notions upon matters even of little importance, incapacitates for accurate thinking on those which are of greater consequence.

It may be desirable, in the first place, to take a glance at the early history of this belief. I have accordingly selected a few of the more important of the facts brought together by the learning and industry of Bishop Horsley, and read by him to the Royal Society in 1774.

Aratus, an astronomer and physician, who lived in the time of Euclid, appears to have been the first to collect, in his book of prognostics, the notions of this kind that were prevalent in his day. That work, owing more, it is said, to the quality of the verse in which it is written than to the interest taken in its statements, procured commentators in abundance among the Greeks and Romans. Pliny relates at great length the celestial signs, Germanicus translated them, and Virgil recommends them to the serious consideration of agriculturists. Aratus prognosticates the weather from a great variety of objects—from the heavenly bodies—from animals, plants, and terrestial objects; but from the moon's aspect in particular, he could predict the weather only from one quarter to another. These predictions were founded upon the indications which the moon gives of the existing state of the earth's atmosphere. Thus, he says, if the moon on the 4th day cast a shadow, the weather will be fine during the remainder of the first quarter—meaning, that the moon at that early stage is a delicate test of the clearness of the atmosphere. Again, the bluntness of the horns in the new moon is a sign of approaching rain, for if the air were clear, they would be of their natural pointed shape. And after the half moon, the horns being then always blunted, other indications are given for predicting the weather till the full moon.

But the vulgar, says Dr Horsley, soon began to consider those things as causes, which had been proposed to them only as signs. The manifest effect of the moon on the ocean, while the mechanical cause of it was unknown, was interpreted as an argument for her influence over all terrestrial things; and these notions were so consistent with the visionary philosophy of the times, that such men as Theophrastus and Varro, who should have been its opponents, ranged themselves on the side of the popular prejudice. Theophrastus says that the new moon is

generally a time of bad weather, the light of the moon being wanting, and that changes of the weather generally fall on the new and full moon, and on the quadratures. Pliny had his eight critical days for changes of the weather, which were the days of new and full moon, the quadratures, and the four octagonals, or rather the nearest odd numbers to these days, viz. the 3d, 7th, 11th, and so on; for besides the influence of these periods, there was much of virtue in the odd numbers. And so great a man as Varro, as he is quoted by Pliny, was not ashamed to give this childish rule for predicting the weather for a month to come, from the appearance of the new moon. "If the upper part of it," he says, "be obscure, the decline of the moon will bring rain; if the lower horn, the rain will happen before the full; and if the blackness be in the middle, we shall have rain at the time of the full moon." Theophrastus and Aratus taught their followers to remark the position of the horns at different times of the moon's age, whether they were erect, inclined, or prone, and thence to take conjectures of approaching fair weather or tempest.

"On the whole," says Dr Horsley, "I do not deny that the observant husbandman will find useful prognostics in the appearances of the moon and the heavenly bodies in general, but they will be prognostics of no other kind than the sputtering of the oil in the industrious maiden's lamp, and the excrescences which gather round the wick. They will show the present state of the air however, and may thereby furnish conjectures for two or three days to come."

The subject has of late years occupied the attention of some of the most distinguished astronomers of Europe, and numerous observations have been made to ascertain the amount of influence exercised by the moon over our atmosphere. Every different position has been carefully investigated, and years of observation have yielded results adverse to the popular impression. A few of these I shall relate, not in the order of their publication, but by taking up each question separately.

1st. *Does a Change of Weather occur at Changes of the Moon, or on the days on which the Moon enters a New Quarter, more frequently than on other days of the Month?*

Dr Horsley registered, during two years, every considerable change of weather that took place, and arranged the results in tables, showing at the same time the day and hour at which the moon entered each of her quarters. During the first of these years sixty-nine decided changes were recorded, and twenty-two of them occurred on days corresponding to the quarters, or octants, which is just four more than their even proportion. But rejecting the changes which were reversed within the twenty-four hours, there remain, out of forty-six changes in all, only ten on the days of lunar influence, which are two less than belong to them on the even chance, for the days of syzygy, quadrature, and octant $= 98$, and $365 : 98 :: 46 : 12\frac{1}{2}$. Of these ten changes, only two coincided with a new moon; two also with a full moon; but they were reversed within twenty-four hours.

During the succeeding year, 1774, Dr Horsley continued his register, omitting however September and November, these two months having been particularly changeable. Here thirty-nine changes occurred in ten months, of which fourteen were on the days specified, being four more than their equal share. Of these fourteen, only four fell on the day of a new moon, and none at all on the day of the full. If we take the latitude of three days before and three days after every quarter, which the popular idea allows, and thus increase the number of the influential days, more changes of the weather would of course occur on such days, but still only the proportien due to that increase of number.

I might here adduce the opposite results of Toaldo of Padua, obtained by computation from a course of fifty years' observations by the Marquis Poleni, and showing that many more changes occurred at the new and full moon than at the first and last quarter; but they seem to be of no value, for it turns out that, *assuming* the moon's influence to be greatest at the change and the full, Toaldo spread these periods over three days, including the day before and the day after, and then compared the changes of weather that occurred on all the three days with those of the single days on which the quarters fell. Toaldo uses an extraordinary argument to enforce his conclusions. "Every one," he says, "is aware, from his own experience, that the nails and hair grow much more quickly when cut during the increase of the moon than when cut during the wane."

In opposition to Toaldo, there are twenty-five years of observations of the different phases of the moon, by Pilgram of Vienna, which give as their result :—

58	Changes of weather	on the days of New moon.
63	—	on those of the Full moon.
63	—	at the Quarters.

The difference is no doubt occasioned by the difficulty of deciding what constitutes a change of weather in the sense understood by Pilgram. Were it otherwise, these results would prove seven or eight per cent. fewer changes of the weather at the change of the moon than at any other period of the lunation—a conclusion at which no one has ever arrived, and which is altogether improbable.

Olbers, the celebrated discoverer of Pallas and Vesta, declares that the experience of many years has convinced him, that at least in the climate of Bremen the rules of Toaldo are utterly false. "We shall be convinced," he adds, "of the smallness of the moon's influence, if we reflect that weather of the most opposite kind occurs in different parts of the world at the same moment, and consequently with the same lunar phase. This is most readily observed during an eclipse when accounts of the weather arrive from many different quarters. The remarks, for example, that were made during the solar eclipse of the 18th November, 1816, have been collected in this way, and furnish a singular mixture of good and bad weather spread on that day over a great part of Europe." Olbers quotes also the observations of Professor Brandes as furnishing results to the same effect.

2d. *Does the Moon influence Rain?*

This question has been investigated by Schubler in a course of twenty-eight years' observations in different parts of Germany. His results were published in 1830, and they seem to show that rather more rain falls during the waxing moon than when it is waning; and also that a greater number of rainy days occur during the first half of the moon's course than during the last. But Schubler's tables being a mean result of mixed observations, they do not bear upon the question in hand; for, whatever change of weather took place at one change of the moon might be balanced by an opposite change at the next—the popular belief acknowledging equally a change from fair to foul and from foul to fair—I will only mention that he found five per cent. more rain to fall during the seven days when the moon was nearest to the earth, than when at the most distant part of its orbit. Schubler's results, as I have said, decide nothing as to changes of the moon producing changes of the weather; but they seem to show that some relation does exist between the moon and our atmosphere. They are affected, however, by too many foreign influences, and are summed up from observations too little capable of precision to entitle the deductions from them to rank among ascertained facts.

3d. *Does the Moon influence the Winds?*

The meteorological tables published in our monthly scientific journals, give the direction of the wind at a particular hour of each day. Such tables, indeed, differ materially when made up a few miles from each other; and they mark the slightest local breeze equally with the most generally prevailing wind. No very important conclusion can therefore be drawn from them; and yet we may expect, from the balancing of the various other causes of change, that if the phases of the moon influence at all the movements of the atmosphere, these movements will be perceptible in summing up the results of a series of years. If it cannot be perceived from such results that the winds change more decidedly at new moons than on the other days of the month, neither can it be noticed by an observer, whose only register is his memory; and it may reasonably be presumed, that changes in the other phenomena constituting weather, which are generally accompanied, if not regulated, by changes of the wind, are also incapable of being traced to lunar periods.

I have chosen, as most convenient for reduction, the register of the winds kept at Chiswick, near London, for the six years from 1838 to 1843. The state of the wind at one o'clock each day is that which is noted. In order that the amount of change from one day to another may be stated in numbers, I have marked as 1 a change equal to one-eighth of the circle;

as, from N. to N.E., or from S.W. to S. A change of two-eighths is marked 2; and the greatest change, viz., from N. to S., or from S.E. to N.W. marked 4—thus,

1838, Feb.	8,	S.W.		
	9,	S.W.	0	Full moon.
	10,	N.E.	4	
	11,	N.	1	
	12,	N.	0	

An abstract is given below of tables drawn up in this manner from observations of six years.

Table showing the Changes of Wind in connection with the Moon's Age.

	1838 12 Moons.	1839 12 Moons.	1840 13 Moons.	1841 12 Moons.	1842 12 Moons.	1843 12 Moons.	Total in 73 Moons.	Sums of five days connected with each quarter.
1 ●	12	12	19	20	8	14	85	396
2	14	11	13	13	11	10	72	
3	12	15	19	17	14	14	91	
4	11	8	14	16	8	14	71	
7	16	13	15	16	13	11	84	
8	16	16	21	13	11	7	84	
9 ◑	16	15	16	16	14	10	87	442
10	16	14	12	23	19	12	96	
11	13	12	20	12	16	18	91	
12	11	6	13	12	9	14	65	
15	21	14	21	23	12	16	107	
16	13	15	20	16	14	17	95	
17 ○	8	15	16	14	20	21	94	447
18	13	11	13	10	10	14	71	
19	8	10	13	23	12	14	80	
20	11	19	16	18	11	24	99	
23	16	13	9	15	14	6	73	
24	6	18	16	18	8	18	84	
25 ◐	9	18	8	14	13	14	76	379
26	7	16	13	12	13	7	68	
27	13	9	15	12	11	18	78	
28	10	10	13	14	10	17	74	
31	11	7	18	11	8	9	64	
32	10	13	22	12	14	13	84	
							1973	
Average,							82	
Do of each year,							13½	

Thus in 1838, on the 12 days of new moon, the amount of change, as compared with the previous 12 days, was equal to 12. On the second day of the moon it was 14. On the 12 days on which the first quarter fell, the changes were equal to 16. It here appears that the average changes for one day of the moon's age in each of the 73 moons is 82, and that 85 changes occurred on the 73 days of new moon, or 3 more than the average. But it also appears, that on the days of full moon and of the first quarter, the changes are still more; and that all of them are exceeded by several of the intermediate days on which no lunar influence is supposed to be exerted. It will farther be remarked, that on the days of the new moon the changes vary from 8 in 1842, to 20 in 1841, and that in three of the years they are below the average of 13½. To account for the omission of certain days in the table, it is necessary to explain that as each quadrature had to be placed in the same line, and the number of days between the quadratures being unequal, blank days frequently occurred in the columns which had been marked the 5th and 6th, 13th and 14th, 21st and 22d, 29th and 30th days of the moon, and that these have been omitted for the purpose of shortening and simplifying the table.

4th. *Have Tides been observed in the Atmosphere?*

They must be assumed to exist by all who acknowledge the moon's influence upon the atmosphere, for scarcely in any other way can such influence be supposed to be exerted. An atmospheric tide, however, like that of the ocean, must twice every day have its ebb and flow—changes quite as great as those to which the effects in question are attributed; and yet we never hear of changes of weather being expected in correspondence with each of these atmospheric waves. But even the existence of any double diurnal oscillation produced in the atmosphere by the attraction of the sun and moon, has never yet been detected. It is altogether insensible to an ordinary barometer. Laplace reduced a great number of exact observations, and found the differences due to those attractions so minute and so variable as to leave him in doubt of their sensible existence. And Arago, to whom we are indebted for much information on this subject, after a minute detail of the observations of Flaugergues and Bouvard, arrives at essentially the same conclusion.

We have no ground, therefore, either from theory or direct observation, for believing that the moon produces any change upon the weather; or, at least, it must be allowed, (to use the words of Dr Olbers), that its influence is so slight as to be lost among the infinite number of other causes and forces which destroy the equilibrium of our easily disturbed atmosphere, and therefore altogether insensible to ordinary observation.

HOPKINS' RESEARCHES IN PHYSICAL GEOLOGY.

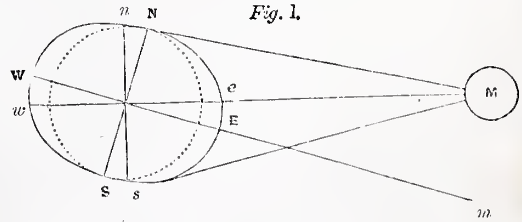
The province of direct geological observation is limited to a small depth below the surface of the earth, and it is only by enlisting in his service the aid of collateral and independent science, that the geologist can be warranted in coming to any rational conclusions in reference to the internal constitution of the earth. And here we cannot but remark in passing, that there has existed and still does exist, to some extent, among geologists even of eminence, some singular prejudices in regard to the legitimacy of the application of the principles of other sciences, in bringing them to bear upon the theoretical discussion of geological science. The most liberal examination of the accuracy of geological principles by the light of distinct and established scientific laws, so far as the nature of the case admits of it, is certainly a most healthful operation, as well because it assists in correcting the erratic hypotheses of one class of geologists, as that it also illuminates and points out the path of future successful inquiry.

It is to general physics on the one hand, and to astronomy on the other, that we must refer for the establishment of certain leading principles, which are essentially necessary to be attended to in conducting the researches of modern geology; and it is our intention in the following article to present an outline of the mathematical inquiries of Mr W. Hopkins into the structure of the globe, which are founded upon certain astronomical data, derived from the effects of the attraction of the sun and moon upon the earth.

It is known that the sun and all the planets and secondaries of the solar system mutually attract each other, with forces directly proportioned to their masses or weights, and inversely proportioned to the squares of their respective distances from each other. It is known, too, that the earth is an oblate or compressed spheroid in form, having its equatorial diameter about 1-300th part longer than the polar; the former being 7899·17 miles, the latter 7925·648 miles, the difference, or compression as it is termed, will be 26·478 miles. In other words, the equatorial parts are 13 miles farther from the centre than the polar.

In the annexed figure 1, let N E S W represent a section of the

Fig. 1.



globe through its axis, of which N and S are respectively the north and south poles. The dotted circle represents the figure of the earth, were it exactly globular; but, being spheroidal, the lunette spaces *n* W *w* and *e* E *s* represent the equatorial protuberances upon the surface, which, as we have already remarked, is 13 miles deep at the points E and W, and constitutes proportionally about

as much alteration of the figure of the globe from a sphere, as a strip of writing-paper would effect upon an orange when wrapped round it. If the earth were a perfect sphere, the moon's attraction would have no disturbing effect upon it. And though it is an oblate spheroid, the result would be the same if the moon's orbit were in the plane of the equator, that is in the position W E *m*, as in this case the force of attraction on the one side of the equator would exactly balance that on the other. But the plane of the moon's orbit is oblique to that of the equator, or in the line *w e* M; and as the distance between the satellite and the earth is only thirty diameters of the latter, the action of the moon M is a little greater on the part of the protuberance next to it, at E, than on the part opposite, at W. The effect of this disturbing action is to draw down the plane of the equator from the direction W E to the direction *w e*, and to produce a corresponding angular change in the position of the earth's axis, shifting it from N S to *n s*. This change of position is called the *Nutation of the earth's axis*, so named from *nutatio*, nodding. The name is appropriate, for the motion is constantly varying in amount, and constitutes a sort of vibration, which runs through its principal phases in eighteen and a-half years, the period in which the moon's nodes complete their revolution. The action of the sun is conjoined with that of the moon, but is comparatively feeble. The secondary effect of this nutation is the *precession of the equinoxes*, or the shifting of the equinoctial points 50″ westward annually, which makes the pole of the earth describe a circle of 47° in diameter round the pole of the ecliptic in 25,800 years.

To give an idea of the extreme minuteness of the change produced by nutation, let us suppose an iron rod 100 feet long, fixed at one end and moveable at the other, to represent one-half of the earth's axis. If the moveable end were pulled *the twentieth part of an inch* to one side, the deviation would be proportionally as great as that which the *lunar* nutation produces in the terrestrial axis.

It appears then that the moon's attraction may be conceived to act upon the part *s* E with the aid of a lever, rather longer than if the earth had been perfectly spherical. The difference is indeed very small; and it is greatly reduced by the obvious fact that the moon's attraction at W tends to counteract her attraction at E, from which it follows that the effective disturbing influence is only that due to the difference of the attractions, which, as we have before premised, are in proportion to the squares of the distances of the parts from the disturbing body, the moon. Adding to these considerations the fact that the mass of the moon is only 1-68th part of that of the earth, it might be inferred that the effect of causes so very minute would be inappreciable. Such an inference, however, would be erroneous. In truth, the *effect* was discovered first, and led to the knowledge of the *cause*. Dr Bradley detected a change in the latitude of the stars, which, after increasing for nine years, diminished for the next nine, and amounted in all to eighteen seconds. He observed that its period coincided exactly with that of the revolution of the moon's nodes, and was thus led to the discovery of the cause.

According to recent experiments with lead balls, originally devised and executed by Cavendish, it appears that the mean specific density or gravity of the earth, is fully $5\frac{1}{2}$ times that of water, or in the ratio of 566 to 100. Now the specific gravity of the superficial parts of the globe, as inferred from experiments upon the most prevalent rocks at the surface, is about 2·5. The interior parts of the globe must therefore be heavier than the exterior rocks.

By viewing the equatorial protuberances at W and E, as a ring distinct from the spherical mass represented in dot-lining, the problem of the effect of the moon's attraction is simplified. Were this ring free to obey the lunar attraction, the effect upon it by itself would certainly be very great; but being, as it is, a part of the whole mass of the earth, it is very much restrained by the *inertia* of the incomparably larger central mass, which it has to drag after it; and hence it undergoes but a very slight change of position.

The magnitude and density of the globe being known approximately, and also the magnitude and density of the equatorial ring the action of a body like the moon, whose mass and distance are known, can be subjected to mathematical calculation.

Mr Hopkins having first investigated the phenomena of precession and nutation on the hypothesis that the earth is of uniform density throughout, in which case the conditions of solidity and fluidity are considered, he passes to the case in which the earth is assumed to be, what it really is, a body whose density is variable, increasing with the depth, and is modified by the conditions of internal fluidity and solidity.

Bearing in mind that the force of attraction is in proportion to the density of matter, it is easy to understand that the relative densities of the masses of the ring and the globe become points of importance as elements involved in the problem. But we have further to inquire into the constitution and distribution of the matter in the interior of the globe. We know that it is solid at the surface. Is it solid to the centre—that is to say, is it composed of parts immoveable *inter se?* We know also from volcanoes, that there is a fluid matter within it, that is, matter whose parts are moveable, and obedient *inter se* to the laws of gravitation, external attraction, and centrifugal force. Does this fluid matter compose a large or a small part of the entire mass? Is it situated near the surface, or at a vast depth? The disturbing action of the moon will not be the same upon a globe all solid, and upon one nearly all fluid; neither will it be the same upon a globe in which the solid shell forms one-half of the mass, and another in which it forms only one-tenth.

Such are the principal points in the problem which Mr Hopkins had to solve; and, after examining the subject in all its bearings, he arrives at the conclusion that, "upon the whole, the minimum thickness of the crust of the globe, which can be deemed consistent with the observed amount of precession, cannot be less than one-fourth or one-fifth of the earth's radius;" that is, from 800 to 1000 miles of thickness.

The conclusion thus arrived at by Mr Hopkins is quite consistent with the mathematical speculations of Fourier, who adopts the hypothesis that the earth is a cooled globe, very hot within, and still cooling slowly. It appears from the investigations of that philosopher on the theory of heat, that the temperature of the surface of our planet being, as we know it to be, wholly dependent on the solar radiation, the interior of the mass may have any temperature whatever, any extreme of heat or cold, without producing any sensible effect on the surface. The reason of this is very simple; the conduction of heat, by the substances near the surface of the earth, is so exceedingly slow, that ages might pass before there could be any sensible warmth communicated from even intensely hot masses placed at a moderate depth. The fluctuations of the solar heat are experienced only to a certain depth, below which the temperature of any one point is invariable. This depth is not everywhere the same, but, as far as yet appears, nowhere exceeds 100 feet. The temperature at this depth is constant, and generally corresponds, at least nearly, to the mean annual temperature of the surface. The temperatures below this depth can only be known by experiment. And it appears to be fully ascertained, that, in situations far removed from volcanic action, in different kinds of rocks with very different chemical relations, water, air, and rocks continually grow warmer as we descend in the earth. *Without a single exception*, the interior of the globe is warmer than the surface, and the heat augments constantly with the depth.

"The results arrived at," says Mr Hopkins, "have an important bearing on our physical theories of volcanic forces, and the mode in which they act. Many speculations respecting actual volcanoes have rested on the hypothesis of a direct communication, by means of the volcanic vent, between the surface and the fluid nucleus beneath, assuming the fluidity to commence at a depth little, if at all, greater than that at which the temperature would suffice, under merely the atmospheric pressure, to fuse the matter of the earth's crust. When it is proved, however, that that crust must be several hundred miles in thickness, the hypothesis of this direct communication is placed much too far beyond the bounds of probability, to be for an instant admitted as the basis of theoretical speculations. We are necessarily led, therefore, to the conclusion that the fluid matter of actual volcanoes exists in subterranean reservoirs of limited extent, forming subterraneous lakes, and not a subterraneous ocean. Such, also, we conclude, from the present thickness of the earth's crust, must have been the case for enormous periods of time; and, consequently, there is a very high degree of probability that the same was true at the epochs of all the great elevations which we recognise, with the exception, perhaps, of the earliest."

In reasoning upon the origin of these subterranean lakes, Mr Hopkins ascribes them to two causes: first, the greater fusi-

bility of the matter composing them; secondly, a relaxation of the pressure which counteracts fluidity. The first cause assigned, is quite according to the analogy of the condition of matter at the surface of the earth, amongst which there exists great variety of fusibility. It is also to be borne in mind that fusion is facilitated by the presence of certain substances which act as fluxes. The greater fusibility of some parts being admitted, Mr. Hopkins shows that it might be sustained or increased by upheavals.

Fig. 2.

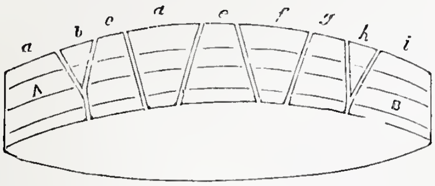
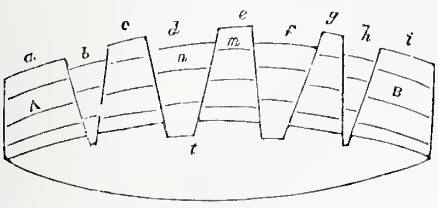


Fig. 3.



For suppose A B, fig. 2, to represent a transverse section of the earth's crust, subjected to an elevatory action, and fissured by it; and let C be a cavity beneath it containing a quantity of fluid matter, the expansion of which has created the elevatory movement of A B. Fig. 2 is intended to represent the separated parts in their *nascent* state, or just before they have undergone any material change of place. Some of the masses, as *b* and *h*, will have the form of complete wedges; others will form truncated wedges with their broad sides upwards, as *d* and *f*; and others again will appear as incomplete wedges in an inverted position, as *a*, *c*, *e*, *g*, and *i*. Suppose now that by the continued elevatory action of the fluid matter, the whole mass is further uplifted; the width of the fissures will not be increased, for the complete wedges *b*, *h*, with their points downwards, will descend by their gravity into a position such as is shown in fig. 3, as the resistance offered by the fluid will be but small; for the same reason also, in a modified degree, the masses *d* and *f*, with their narrow sides downwards, will also descend. Thus, by the resulting arrangement in fig. 3, the parts of the whole mass will form an arch which will sustain itself. Supposing now the swelling of the fluid to cease, and that it returned to its original dimensions, the pressure of the mass A B will be removed from it; and hence, "assuming that solidification is promoted by great pressure, it evidently appears how a portion of the interior mass might be maintained in a state of fluidity by the removal of a superincumbent pressure, which would otherwise have brought it to a state of solidity. It is not essential to assume that the arch shall entirely support itself. It may be partly supported by the fluid beneath, or it may break down in certain points, or along certain lines, and form there new supports intermediate to the extreme ones. Instead of one continuous internal lake, a number may thus be formed, connected with each other by more or less obstructed channels of communication."

Mr Hopkins' hypothesis, just explained, regarding the process of elevatory movements has the merit of explaining very happily a phenomenon attending these movements which has hitherto puzzled geologists. And we may remark that this application of his hypothesis has been first suggested by Mr Charles Maclaren:*—When *faults*, or shiftings of the strata, occur in mines, it is always found that the dislocated portion is to be sought above or below, according as the line of fault, traced downwards across the bed, inclines outwards from, or inwards to, its plane. Thus, if *m*, a bed in the mass *e*, is cut off by the fault *t* dividing *e* from *d*, the miner seeks for the prolongation of it downward, and will find it at *n*, because the line of fault *t* inclines outward from the plane of the bed. If, again, he had been working on *n*, he would have sought the prolongation upward, because the angle inclines in the opposite way. The explanation is, that the fluid matter in the cavity C exerts a greater pressure on the masses *a*, *c*, *e*, *g*, and *i*, whose broad sides are downwards, than on *b*, *d*, *f*, and *h*, whose narrow sides are downwards, and in the general movement the former are therefore pushed farther up than the latter. Or, to express it in another form, the latter slip down till their immersion in the fluid counterbalances the narrower surface exposed to its pressure.

The hypothesis of fluid matter existing in isolated cavities at a moderate depth, affords an easy explanation of some volcanic phenomena by means of the agency of watery vapour, which is known to be always present.

"Professor Bischof of Bonn," says Mr Maclaren, in the paper already referred to, "calculates that steam, at its maximum elasticity, is capable of supporting a column of liquid lava 17 miles in height. The depth at which the internal heat of the globe would suffice to keep lava in a state of fusion, is estimated at 20 or 30 miles; but the data are too imperfect to indicate the ratio of increase with any certainty. The increase, too, may follow a geometrical, instead of the arithmetical ratio assumed; and in this case the depth will be much less. Besides, if there is an excess of heat at the bottom of a reservoir, the matter may be kept fluid by circulation, to a level much nearer the surface than the supposed limit of fusing temperature. Watery vapour, also, may not only reach the cavity containing the fluid matter, but may mingle with it through chinks in the volcanic vent; and, we may thus have a continual alternation of columns of lava and steam rising in succession, the consequence of which would be an alternate ejection of lava, red-hot masses, and clouds of vapour, as well exemplified at Stromboli.

"Now, to enable the steam to exert the prodigious force required, we must suppose both it and the lava on which it acts to be lodged in a cavity, surrounded on all sides by solid resisting walls, with no opening but the volcanic vent and the chinks by which water is admitted. If lava were part of a central fluid nucleus, water reaching it at any point, after being converted into vapour, would glide along the under part of the solid crust, and settle at the highest vaulted cavities, till additions to its quantity or its temperature enabled it to open a passage for itself, or for a portion of the lava, through the crust. Water passing downwards from the ocean near the shore, might thus create a volcano at the distance of 500 or 1000 miles inland, as readily as near the coast. But the fact of all active volcanoes being near the sea, or large bodies of water, is at variance with this supposition. On the contrary, it lends support to the conclusion, first, that water is a necessary agent in volcanoes; and, next, that the fluid matter upon which it acts exists in isolated basins of various forms and dimensions, confined within solid rocks. Thus, one basin 150 miles in length may exist under southern Italy, connecting Vesuvius, the Lipari Isles, and Etna. There may be one 200 miles in length and breadth, under Iceland; and a vast trough 4000 miles or more in length, but of comparatively small breadth, may extend under the Andes. The sudden and simultaneous activity of three volcanoes in the Cordillera, far distant from each other, which broke out from a state of repose into violent eruption on the same day, favours the idea of a subterranean connection between them; and the existence of an almost continued line of craters in the intermediate spaces, strengthens the probability of such a connection. If the volcanoes at the two extremities of the line sympathize in their action, we would expect all the intermediate parts to be disturbed less or more; and the extreme frequency of earthquakes in the Andes (often several in a day) may thus be the natural consequence of the long series of craters, the activity of any one of which will agitate the whole chain in a less or greater degree."

We shall now examine the state of the general theory of convulsive movements, and present a sketch of the conclusions of Mr Hopkins on the subject. The first ideas respecting the direction of convulsive movements were formed by miners, who in course of their experience observed, as an important practical fact that, amidst many directions, the prevailing direction of mineral veins which were most generally and uniformly productive, lay east and west, or nearly so; and that those "right running" veins were intersected by "cross courses" passing at right angles to them, or nearly so. But, as Professor Philips observes,†

* Outlines of Hopkins' Researches, in the Edinburgh New Philosophical Journal.

† Treatise on Geology.

"it is to M. De Beaumont that we owe the proposal of the direction of convulsive movements, as a new and important problem in geology. He supposes that disturbances of the same system or geological era are parallel to a certain great circle of the sphere; that those of different periods are related to different circles, the poles of these circular systems being very irregularly posited on the globe. There are facts which make for and against this hypothesis, but it is difficult, in the present state of our knowledge, to come to a right conclusion on the matter. It is very difficult to know the relative ages of *distant* convulsions, because the lines of contemporaneous stratification are often entirely unknown. Adjacent convulsions, even if parallel, cannot prove a rule which is to apply to a whole circle; moreover, local variations of a line of convulsion sometimes derange all the reasoning. Under these circumstances, it is clearly impossible to adopt De Beaumont's hypothesis, for want of evidence either exact or extensive enough to substantiate it. But yet entirely to reject the principle which it involves, would be not only rash, but positively contradictory to important facts. That some symmetrical accordance does really exist, and is traceable between the dislocations of a particular age in a particular region, is certain; and some cases are known of this symmetry being more extensively recognised."

In Mr Murchison's Notes on the Silurian system and the adjacent igneous rocks,* there are many instances of the local parallelism of ridges of trap, and anticlinal axes in these ancient rocks, combined with some general directions of dislocation. The prevailing strike of all these deposits is north-east and south-west, or parallel to the Snowdonian chain, from Shropshire to the mouth of the Towey, a range of 100 miles. Within this space are numerous minor axes of dislocation, short, but parallel to the same great strike of the beds; the beds dipping north-west and south-east, from ridges of trap. This general line of dislocation is broken through by transverse rents and fissures. A north-eastern strike belongs to the Ludlow rocks and the old red sandstone. On the eastern side of the red sandstone of Herefordshire, the ridges of Abberley and Malvern point north and south, but are complicated by minor ridges running in different directions.

Upon the whole, then, it may be inferred, that the results of observation, in connection with the experience of miners, point to the existence of some common principle, according to which there exists, in particular, a tendency to local parallelism and rectangulation among the lines of dislocation in a given region, This leads us to the investigations of Mr Hopkins on the subject,† who, with the aid of some simple and probable assumptions, has deduced a series of dynamical results for comparison with observation. "The hypotheses from which I set out," he remarks, "with respect to the action of the elevatory force, are, I conceive, as simple as the nature of the subject can admit of. I assume this force to act under portions of the earth's crust of considerable extent, at any assignable depth, either with uniform intensity at every point, or in some cases with a somewhat greater intensity at particular points; as for instance, at points along the line of maximum elevation of an elevated range, or at other points where the actual phenomena seem to indicate a more than ordinary energy of this subterranean action. I suppose this elevatory force, whatever may be its origin, to act upon the lower surface of the uplifted mass, through the medium of some fluid, which may be conceived to be an elastic vapour, or, in other cases, a mass of matter in a state of fusion from heat. Every geologist, I conceive, who admits the action of elevatory forces at all, will be disposed to admit the legitimacy of these assumptions.

"The first effect of an elevatory force, will of course be to raise the mass under which it acts, and to place it in a state of extension, and consequently of tension. The increase of intensity in the elevatory force, might be so rapid as to give it the character of an impulsive force, in which case it would be impossible to calculate the dislocating effects of it. This intensity and that of the consequent tension, will therefore be always assumed to increase continuously, till the tension becomes sufficient to rupture the mass, thus producing fissures and dislocations, the nature and position of which it will be the first object of our investigation to determine. These will depend partly on the elevatory forces, and partly on the resistance opposed to its action by the cohesive power of the mass. Our hypotheses respecting the constitution of the elevated masses, are by no means restricted to that of perfect homogeneity; on the contrary, it will be seen that its cohesive power may vary, in general, according to any continuous law; and moreover, that this power, in descending along any vertical line, may vary according to any discontinuous law; so that the truth of our general results will be independent, for example, of any want of cohesion between contiguous horizontal beds of a stratified portion of the mass. Vertical or nearly vertical planes, however, along which the cohesion is much less than in the mass immediately on either side of them, may produce considerable modifications in the phenomena resulting from the action of an elevatory force. The existence of joints, for instance, or planes of cleavage, in the elevated mass, supposing the regularly jointed or slaty structure to prevail in it previously to its elevation, might affect in a most important degree the character of these phenomena. To a mass thus constituted, these investigations must not be considered as generally applicable."

After summing up the mathematical results of the investigation, the author applies them to the case of a portion of the earth's crust. And first, in regard to longitudinal fissures, in the case of a mass of indefinite length, bounded laterally by two parallel lines, with the elevatory force uniform, the extension, and therefore the tension, will be entirely in a direction perpendicular to the length, so that its whole tendency will be to produce *longitudinal* fissures, or such as are *parallel to the axis of elevation*. These fissures will not commence at the surface, but at some lower part of the mass. The whole series of stratified rocks existing above an originating line of fissure, will be affected by the tension producing it; but under certain cases the fissures may not reach the surface. The width of the fissure will be nearly the same at all depths of disturbed strata (varying, however, with their elasticity). Any number of these fissures might be formed simultaneously, more, it is probable, in the deeper parts. Thus there are complete and incomplete fissures, all parallel to the axis of the uplifted tract.

Again, if the elevatory force be supposed to act with greater intensity at particular points along the general line of elevation, or an additional force *superimposed* on a uniform force, the axis of elevation will be undulated by one or more cross ridges and hollows; and parallel to these another system or systems of fissures may be produced, circumstanced like the longitudinal fissures previously mentioned, as to completeness, width, &c., but ranging across *the axis of elevation*, and approximately perpendicular to the longitudinal fissures. This result is almost independent of time: the transverse fissures may be instantaneously following, or very long subsequent to the longitudinal fissures. These theoretical deductions are well supported by facts.

Fissures of a conical elevation, if produced solely by forces of great intensity and limited area, will commence along or very near to the axis of the cone, and be continued in a vertical plane, passing through the axis. If such forces were exerted *simultaneously* with those determining a general axis of elevation and fissures parallel thereto, the result would be a local convergence of such longitudinal fissures towards the axis of the conical elevation, beyond which they would resume their parallels. A contrary deviation of these fissures would follow upon a spherical elevation.

Lastly, by the decrease of the expansive forces which produced the tensions occasioning the fissures, the equilibrium of the divided parts would be destroyed, and they might rest in unequal elevation above their original level, thus producing longitudinal and transverse faults. Anticlinal, synclinal, and simple faults, are thus easily understood to be all consequences of the new positions taken by the divided rocks upon the cessation of the sustaining forces.

Upon the whole, Mr Hopkins arrives at the following important conclusion:—"If the approximate accuracy of our assumptions be allowed, as applied to the crust of the globe, it appears from our investigations that an elevated range characterized by continuous systems of longitudinal and transverse fissures, referrible to the causes to which we have been assigning such phenomena, could not be produced by successive elevations of different points, by the partial action of an elevatory force. In such elevations, fissures would necessarily diverge in all di-

* Geological Proceedings.
† Cambridge Transactions.

rections from the central points, so that parallel systems, such as have been mentioned above, could not possibly be thus produced. Every system of parallel fissures, in which no two consecutive fissures are remote from each other, must necessarily have had one simultaneous origin."

We shall conclude this article by a brief notice of some hypothetical ideas of Mr. Hopkins, upon the formation of the earth. Supposing it to be originally fluid, it might become solid in two ways: the heat would be constantly dissipated from the surface, and would of course be most intense at the centre; consequently, a circulation of the materials would be incessantly kept up.

If the effect of heat in preventing solidifications were greater than that of pressure in assisting it, the conversion of the mass into solid matter would necessarily commence at the surface, whence it would progress inwards in layer after layer. If, on the other hand, the reverse were the case, the solidifying effect of pressure being much greater than the power of the heat to resist that effect, solidification would commence at the centre, and extend outwardly; and while a solid necleus was thus being formed, the extreme fluid portion would ultimately acquire a state of semi-fluidity; when the power of circulation, which hitherto preserved in it the fluid state, would cease, and solidification would commence at the circumference, and progress rapidly downwards. In this way, the earth would arrive at a state in which it would be composed of a solid envelope, or crust, enclosing a solid nucleus, separated from the shell by a spherical medium of fluid matter.

HICK'S EXPANDING MANDREL.

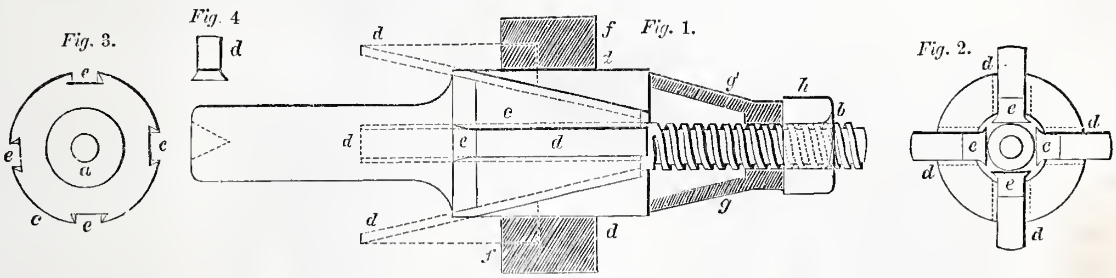


Fig. 1, *a b* the mandrel; the middle portion *c* is made conical, and has four dovetailed grooves, *e*, made in the direction of its length, which receives the four wedges *d d d d;* these are represented at their lowest place, so as to enter the smallest-sized hole to which the mandrel is suited; the hollow block *f f* represents the work, and is placed on the four wedges: these are followed by the hollow conical collet *g g*, and then by the screw nut *h* on the screw *b*. The cone *g*, when urged forward by means of the nut, will drive the four wedges *d d d d* up the inclined grooves, and thus fix the mandrel quite tight and concentric into the hole in the block *f*; the collet *g* is made hollow, in order that it may pass over the cone *c*, and drive up the wedges *d* to any required distance. The dotted lines *d d d* represent the wedges at the extremity of their range, within the limits of which the mandrel is adjustable to the smallest degree of difference in the inside diameters of various articles.

Fig. 2 is a view of the mandrel from the end *b*, without the conical collet *g* and nut *h*, the wedges *d* being pushed up to the largest diameter; *e e e e* the lower parts of the grooves in which they slide. Fig. 3 is a view of the large end of the cone *c*, showing the upper ends of the grooves *e e e e*. Fig. 4, an end view of one of the wedges.

The grooves *e* are cut with an engine, so as to be perfectly concentric; the wedges are then fitted in, and bound tight at the lowest place, and there turned quite true and cylindrical; and by means of a smaller collet than *g*, their ends may be turned true and flat; the collet *g* will then always advance them equally.

APPARATUS FOR RAISING LOADS FROM MINES, PITS, &c., BY A CONSTANT MOVEMENT.

BY M. CAVÉ, ENGINEER, PARIS.

Much attention has been given, for some years, to the object of contriving a safe and efficient apparatus for raising loads from the bottom of mines, and particularly coal-pits, and for carrying up and down the workmen employed; but all the machinery hitherto contrived for the purpose has generally been complex, difficult of application, and more or less subject to accidents. One important objection to all existing contrivances is, that they operate by an intermitting movement.

In the system proposed by M. Cavé, whose mechanical inventions and improvements are always remarkably effective for the end in view, the operation is accomplished by a constant or continuous movement, without loss of time or danger of accident.

This apparatus is applicable to the raising and lowering of loads, either in mines, coal-pits, or stone-quarries, and in general to every operation, having for the end in view the conveyance up and down of men and materials.

It consists simply of an arbor communicating with the prime-mover, which transmits a continuous rotatory movement to two wheels or flanged pulleys, carrying each an endless chain with elongated links, which, at certain fixed distances, are armed with projecting hooks or pins; and on these the ears or buckets are suspended by means of braces formed like the handles of a basket.

At the lower part of the apparatus, or the bottom of the shaft or quarry, a tramway is constructed so as to pass between the chains, and on this the loaded waggons arrive in succession, so as to be hooked by their ears or handles to the pins with which the chains are furnished, at the very moment of their passing upward. Carried by this means to the top, the waggons pass round the flanged pulleys, descend a little beneath them, and are then intercepted, spontaneously detaching themselves from the chains, and resting on another tramway, which passes in like manner between them.

A second similar apparatus may be placed near the former, to take the empty waggons at the top, and descend with them to the foot of the shaft.

M. Cavé proposes, however, to obviate the necessity of this second apparatus, by establishing towards the top and bottom of the shaft a kind of moveable frames, which may constantly convey the waggons to the two chains, either for raising them or letting them down.

The reader will be able to form a sufficiently correct idea of this new system, by the following details in explanation of the annexed figures.

Fig. 1 represents a front elevation of the apparatus, with a vertical section made along the axis of the shaft to which it is applied.

Fig. 2 is a lateral elevation, the plane of section in this case being perpendicular to the preceding.

It will be seen that the apparatus consists of two parallel pulleys, G, octagonal in the section between their checks, and fixed at the extremities of two iron axes, H, which are each impelled by the toothed wheels, I, gearing with the pinions, J, which are mounted on the same journal, K. This last is the shaft communicating with the prime-mover, and may either be impelled by a steam-engine or by water-power.

Over the flanges of the two pulleys, G, pass the endless

Fig. 1.

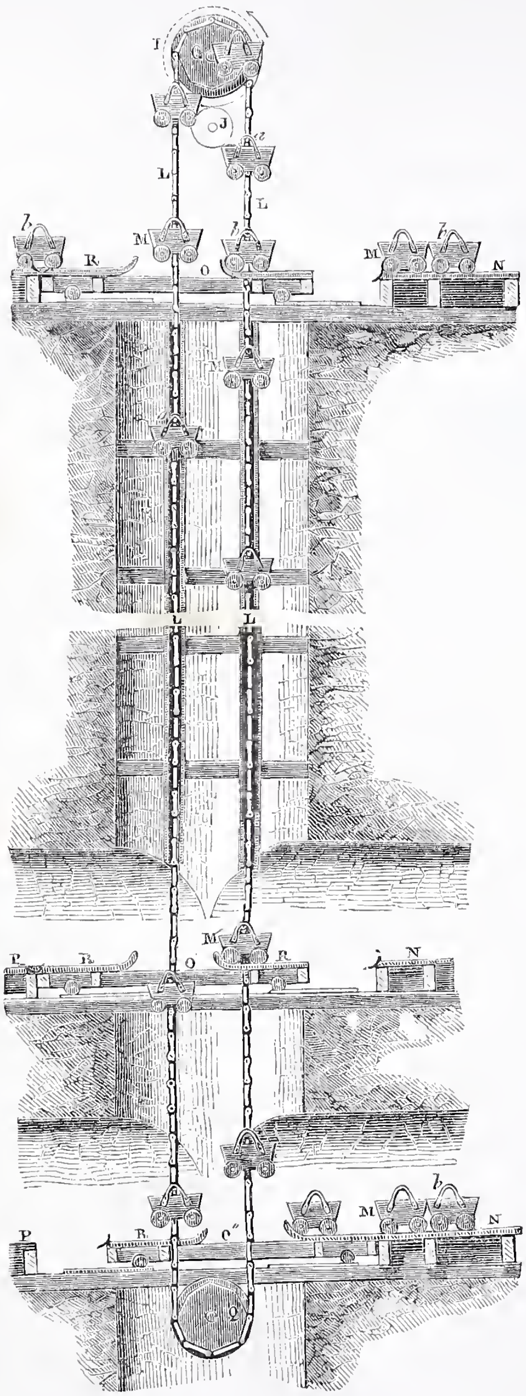
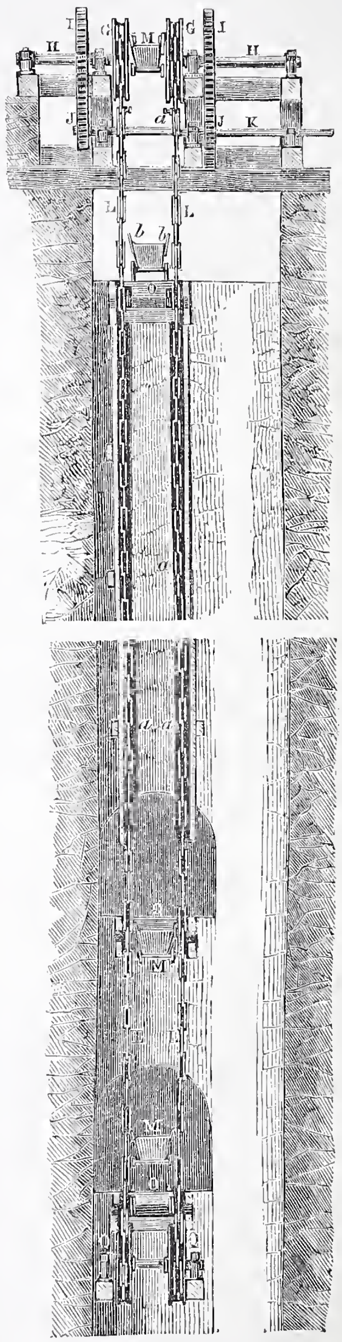


Fig. 2.



chains, L, the links of which exactly correspond in length to the sides of the octagonal periphery of the former. Each of these chains carry, at fixed distances, projecting hooks or pins, *a*, for the purpose of receiving in suspension the waggons, M, in the process of rising or being lowered.

These waggons, which are each formed of a single box mounted on four wheels, are furnished on each side with iron loops or ears, *b*, which present themselves between the two chains, and are hooked on the pins attached to the latter as they pass.

Thus, at the height of the first gallery, the waggon, M, (which has been conveyed either directly by the tramway, N, or by the intervention of a horizontal car or moveable frame, O,) is hooked to the two pins of the ascending parts of the chain, and is consequently drawn up to the top of the apparatus. It then descends again, remaining always suspended by the same pins, and falls exactly on a tramway, P, laid at the entrance to the gallery, and leading to the spot where the waggon is to be emptied.

By making the chains descend to the lower part of the shaft, where they pass over two parallel pulleys, Q, similar to the first, and mounted on the same axis, they can discharge at the same time several successive galleries, situated at different stages. Thus there are two galleries shown in the annexed cuts, which may be supposed to be at any distance, the one above the other.

When the same mechanism or apparatus is intended to serve for raising the loaded waggons, and lowering them again when empty, the inventor places at the mouth of the shaft, and at the opening into each gallery, cars or moveable frames, O, O^1, O^2, which, being formed simply of a wooden truck mounted on four wheels, carry at each end short rails, R, for receiving successively each of the waggons about to be hooked on the chain, either for raising or lowering them. These trucks receive at fixed intervals a come-and-go movement, by means of a very simple mechanism which has been contrived by M. Cavé for the purpose.

This mechanism consists of a lever beam, placed, like the rest of the motive power at the top of the shaft, and to the extremity of which is jointed a vertical rod receiving an alternating movement, by a very obvious arrangement, connecting the other extremity of the lever with one of the principal axes of the apparatus. The vertical rod is connected with each of the moveable frames or trucks by levers, bent at a right angle, which oscillate on their axes or fulcrums fixed into horizontal beams.

From this arrangement it results, that each time the rod is drawn up, it causes the trucks to move from left to right, and *vice versâ*. By this alternating movement, the frames are brought into communication at one time with the tramway on the right, P, at another with that on the left, N; and thus serve the double purpose, either of delivering the waggons which have been deposited by the chains, or of placing the waggons so as to be caught by the chains, for the purpose of lowering or raising them.

All this additional apparatus of trucks or moveable frames, and the mechanism requisite to give them the desired movements, are not required when two similar sets of chains can be fitted up in the same shaft, with corresponding machinery to drive them; for then the one may be exclusively employed in raising the loaded waggons, and the other for lowering them when empty.

DOMESTIC MEDICINE.

CHAPTER IX.

ON THE GENERAL MANAGEMENT OF CHILDHOOD AND YOUTH, AND ON THE DISEASES INCIDENT TO THAT PERIOD OF LIFE.

THE period of *childhood* may be said to include the years which intervene between the completion of the first and the completion of the second dentition, or from about the end of the second to the seventh or eighth year.

The period of *youth* comprehends that space which intervenes between the seventh or eighth year to the age of puberty, which, in this climate, generally occurs at from the twelfth to the fourteenth year in females, and from the fourteenth to the sixteenth year in males.

During this epoch of life—from the time the first, or milk set of teeth are cut, till the age of puberty—the growth of the various organs of the body, and the development of the mental faculties, proceed at a very rapid rate. The limbs become stronger and more active; the flesh and soft textures acquire firmness and increased bulk; the bones enlarge, become harder and firmer, and much more adapted for supporting the weight of the body and for defending the internal organs from injury; the functions of digestion and nutrition, of secretion and excretion, are much more perfectly performed; the organs of sense and all the mental faculties improve in power and energy, and, towards the end of this epoch of life, the distinctions of sex, both mental and physical, become more and more prominently marked.

During the accomplishment of these important changes, the circulation of the blood becomes less and less rapid, the pulsations of the heart and arteries less frequent, the breathing more regular and slow, the nervous system less susceptible of impressions by slight causes, and the acute sympathy between the skin and internal organs, which is so visible during childhood, becomes considerably diminished.

In no part of the body are the changes which arise from an increase of development more decided, or productive of more important effects, than in the brain. During the earlier stages of infant life, the growth of the brain, and the consequent size of the head, increase at a remarkably rapid rate. For the accomplishment of important ends, the size of the head is small at birth, the bones of the scull are loose and compressible, they are detached from one another, and, in many places, particularly at the upper part of the forehead, or *anterior fontanelle*, they form a very deficient covering for the brain; it is not, indeed, till about the fifth year that these openings are completely closed. Instead, however, of this being any defect or imperfection, it is of the greatest use in permitting the rapid expansion of the brain, occasioned by the growth of that organ, and by the congestion or determination of blood to the head, which often takes place during teething; this conformation serves also to mitigate the effects of falls or blows on the head, to which children are so liable during the first years of their life. A rapid increase of size, however, is not the only change which the brain undergoes during the period of childhood. From the completion of the first dentition till the age of seven or eight years, the brain assumes a remarkably different structure; it acquires, from year to year, a much greater degree of firmness and consistency, and contains a less amount of blood. It is in these, and other physiological facts, that medical men see so many and so cogent reasons for advising that this organ be not stimulated to undue activity by any sort of forced education and mental training, till it has acquired a sufficient degree of strength and consistency to permit of such exercise without imminent risk to the health and life of the child.

If the constitution is sound and free from hereditary disease—if the child has not suffered from previous illness, or from the effects of early mismanagement, as it advances in age, and gradually acquires strength and vigour of body, it will be more enabled to withstand the different causes of disease to which it may be exposed. Except, therefore, two or three epidemic and unavoidable complaints, such as hooping-cough, measles, &c., to which all children in this climate are subject, the diseases of childhood and youth are, or ought to be, very few and very simple; by following the instructions in regard to the period of infancy which we have previously given, and adopting the general plan of management we are about to recommend, the period of childhood may be passed, and the age of puberty reached, by the generality of children, with very little trouble to their parents, in a medical point of view. But in after years, when the excesses and improprieties of youth begin to tell upon even the soundest constitution, or when a person has been subjected to any of the various causes of disease previously enumerated, acting either by themselves, or in combination with the effects of these excesses, it is *then* that the human body is so liable to fall a prey to the innumerable and serious diseases which baffle medical skill and shorten man's existence.

GENERAL MANAGEMENT OF CHILDHOOD AND YOUTH.

Food.—In addition to the instructions which are given in last chapter, regarding the food of infants after weaning, we have little to say farther than to repeat, that no regular system,

or fixed theory of diet, can be given, which will apply to all cases, under all circumstances; and to tell those who adhere, with unreflecting obstinacy, to such an opinion, that, sooner or later, they will have ample reason to repent of their folly. The four following requisites of a proper dietary, however, ought to be as closely adhered to as possible.

1. *Regularity in the hours of meals.*

2. *Food of a mixed, but of a plain, simple, and nutritious quality.*

3. *A careful avoidance both of any excess or deficiency in the quantity or quality of nutritious ingredients.*

4. *An absolute prohibition, under ordinary circumstances, of wine or malt liquor, and of stimulating condiments, such as mustard, pepper, &c.*

1. From the earliest age the child should be fed at fixed and regular hours, and, till about the age of two or three years, the intervals between the meals are so short as not to admit of any pieces of biscuit or bread being given with impunity during these periods. As the age advances, however, and these intervals gradually lengthen, there can be no solid objection to allow a child a piece of plain bread or biscuit, if we are certain that it suffers from *real* hunger, and is not giving expression to a morbid craving for some variety in its occupation, or is expecting to be supplied with some sweetmeat or other dainty, which should invariably be denied.

2. It is in accordance both with reason and experience, that the plainer and simpler the food, the better adapted will it be for the healthy nutrition of the child, and the less productive of those derangements of the stomach and bowels which so often arise from improper food. The diet of children ought neither to be exclusively animal nor exclusively vegetable, but a mixture of both, in such proportions as to suit the individual constitution, age, and appetite of the child. Salt meat, stewed dishes, animal food too much or too little cooked, the indiscriminate use of slops, tainted fish or flesh, highly seasoned articles, new cheese, baked pastes, pies, tarts, and the boiled dough of puddings, and uncooked vegetables, are all objectionable, and some of them very highly so, as articles of food for children. None of these things should appear on the nursery table, or in any way be brought into a child's sight, if he is to be denied its use, as nothing is more apt to excite a desire of gratifying the appetite by stealth, or to lay the foundation of that gluttony or gourmandism which shows itself in after-life, than habitually denying children the luxury of tasting those dainties which they see grown-up people eating with so much relish, and which they imagine, by the very prohibition of their use, to be more gratifying to the taste than they really are. On this account it is much better to allow the occasional use even of pastry and sweetmeats, to children above two years of age, and more particularly if they are in the way of seeing them used at table.

In guarding their children against the use of improper food, parents often fall into the opposite error of denying the use of necessary articles of diet, a remark which applies, in a special manner, to the general prohibition of *ripe fruit.* A moderate use of good ripe fruit from the garden, such as strawberries, gooseberries, &c., or of good oranges, grapes, &c., is not only in accordance with nature's instinctive desires—the gratification of which will be often attempted, if good ripe fruit is interdicted, by the use of unripe and improper fruit—but an occasional allowance of good fruit will be found very cooling and wholesome to children, if not carried to excess.

3. There are people who hold the opinion, that the more nutritious the food, and the more they can cram into the stomachs of their children, the stronger and healthier will they be. There are others who hold an exactly opposite opinion, and condemn their offspring to follow the example of the inhabitants of tropical climates, by confining them to a sparing diet, exclusively composed of vegetable and farinaceous substances. Between these two *extremes*, however, there is a *golden mean—a mixed, plain, unstimulating*, and *moderately nutritious* diet for children, which will be adopted by all who follow the dictates of nature on this subject.

4. The stomachs of healthy children and young persons, till far beyond the period of youth, are fully capable of accomplishing all the offices of digestion without the aid of any stimulus whatever. Wine, spirits, and malt liquors of all kinds, are not only *wholly unnecessary*, and, on that account, ought to be prohibited, but their habitual use is absolutely prejudicial in any shape or form; it can only serve to bring about a very bad habit of body, an inflammatory state of the blood, and, in nine cases out of ten, will be productive of the worst consequences in after-life.

With the single exception of salt, and, perhaps, a little vinegar and lemon juice, the use of *condiments*, as mustard, pepper, pickles, &c., ought on no account to be permitted to children and young people; when taken to any extent, even by grown-up persons, they are attended with hurtful effects, except in those long habituated to their use.

Clothing.—The great object of clothing being to serve as a protection from cold, the best way to effect this object is to have every part of the body covered with *warm*, *light*, *simple*, and *easy-fitting* clothes.

When will the caprice of fashion give way to common sense? When will parents throw aside their weak and petty vanity, and clothe their children in accordance with the laws of nature and the physical necessities of the infant frame? The great majority of mothers—in the middle ranks of life, at least—never for one moment think of what shape of dress, or what texture, will most effectually protect their children from the effects of cold, and from sudden changes of temperature, in a moist and variable climate; their sole aim is to make the child represent *their* beau-ideal of *smartness* and *neatness.* But let them remember that such smartness and neatness are effected at the invariable risk, and often at the expense, of the health and life of the child, and that, at the shrine of the demon *Fashion*, many thousands of British children are sacrificed every year.

Some parents, again, err on different but equally false principles, by clothing their children slightly, leaving great portions of their legs, knees, and arms uncovered, for the purpose of making them robust and hardy. But let such parents reflect seriously on the fact, that it is impossible to harden a generation without sacrificing the weaker members; and this could be accomplished far more scientifically, and at an infinitely less amount of suffering to the child, by adopting the practice of some savage tribes, who kill their weakly infants soon after their birth! The mother or nurse may feel warm and comfortable, because warmly clad,—the child may be amused by being out of doors, and it may give no signs of suffering, because cold does not produce its bad effects at the moment of its application,—while, during all this time, the seeds of disease are taking firm root, and will assuredly show themselves, sooner or later, in inflammation of the lungs, windpipe, bowels, or brain. But, because these effects do not immediately follow, the connection between cause and effect is lost sight of, and the health and constitution, or even the life of the child, is destroyed, by the frequent repetition, or the long duration, of a cause which is never suspected by the parents or nurses, from its not being in visible operation at the time of the attack.

It is an utter wasting of words to tell a mother that the pressure of stays acts as a powerful cause of disease in her young daughter, by an undue compression of the internal organs; that if the free action of the lungs, stomach, heart, and liver, be in the least degree interrupted,—which it always is to a greater or less extent by the use of stays,—such confinement and interruption will prevent the necessary growth and bulk, and will render her peculiarly liable to consumption, disease of the heart, indigestion, &c.; *as long as* a mother labours under the delusion that a small waist and slender body constitute the ideal of beauty and the perfection of the human form, so long will she persist in sacrificing everything —health, strength, and even life itself—at the shrine of that capricious goddess, fashion, which rules her with despotic sway. It is equally useless to lecture her upon the impro-

priety of cramping her child's feet by tight and ill-fitting shoes, and telling her how productive such compression of the feet is of corns and other tumours; till she lay aside the Chinese notion that unnaturally small feet is a beauty, she will turn a deaf ear to all such remonstrances. Until, indeed, female education is based upon sounder principles, and until a general outline of human physiology is made one of its elements, medical philanthropists may write and talk, but they will write and talk in vain upon all such subjects.

To parents who are not slaves to the caprice of fashion, and are not obstinately wedded to the antiquated notions they have imbibed from those nurses and old women who fancy themselves much better instructors, on such subjects, than medieal men, although the latter have not only an intimate knowledge of the structure of the human body, but have made the causes of its disease a special object of inquiry, reflection, and study,—to such parents we would urgently recommend the following advice:—

Let the dress of children be *warm* in winter, spring, and autumn; let it combine *lightness* with *warmth* in summer, and let it be *simple*, and constructed in such a manner as to place no restraint upon the motions of any part of the body. If the pecuniary circumstances of the parents are incompatible with fine outer clothing, and a sufficiency of inner garments to insure frequent changes, by all means sacrifice the fine clothing to attain the latter object. Whether the child under two years of age has worn flannel next the skin or not, in such a variable climate as Britain, and particularly when they come to be exposed to cold and wet, children above this age ought to have a waistcoat of fine flannel next the skin, at least during autumn, winter, and spring; and if they show the least disposition to weakness of constitution, affections of the chest or bowels, they ought not to throw it aside even in summer. It is said to be more conducive to health to leave it off during the night; but children so often uneover the upper parts of their bodies during sleep, that, in our opinion, they ought to be provided with one flannel waistcoat for the day, and another for the night.

Let children, therefore, have "frequent ehanges of comfortable and clean clothing, no undue exposure of neck, arms, or legs, and an entire avoidance of unequal or undue pressure by corsets, shoulder-straps, tight shoes, &c."* "The only way we can assist in forming a really fine figure, is to remove all restraint, and secure, as far as possible, so free an action to the muscles as will lead to their perfect development."†

Cleanliness.—To what has been already said on this subject little need now be added, except an injunction to scrupulous exactness and attention to frequent changes of clean clothing, and a rigid adherence to the daily ablution of the whole body with cold water and yellow soap, followed by brisk friction with a soft flesh glove or rough towel.

Every nursery ought to be provided with a large shallow tub, in which the child could sit or kneel, and first be washed, or, if old enough, wash himself all over with a large sponge, then make two or three plunges amongst the water, and afterwards be quickly dried, rubbed, and dressed; the face, neck, and ears should then get an additional washing; the nails, teeth, and hair, ought to be carefully cleaned and brushed every day; everything, in short, should be done to make the child acquire habits of cleanliness, even to the extent of debarring him from the company of the family till he is in every way fit to make his appearance at table.

During infancy, the head requires great attention, and ought to be washed every day; but after two years of age once a-week will be sufficient, if it is carefully combed and brushed every morning. The hair of boys ought always to be kept short, being most conducive to health; and even in girls, under twelve, long hair, when it is allowed, as it often is, to become a receptacle for all kinds of filth and vermin, is not only very disgusting, but most prejudicial to health. Unless, therefore, parents or nurses have ample time at their command to devote to its thorough cleaning every day, the hair of young girls had far better be kept at the length of three or four inches at most.

In washing the head, soap ought to be used, or what is recommended as preferable, both for the growth of the hair and the removal of scurf and seales—the yolk of an egg.

Sleep.—As the child advances in age, a less amount of sleep will be sufficient; but, as we remarked in last chapter, an hour or two's sleep in the middle of the day, for the first three or four years, is of the greatest utility in restoring that vital energy which is so soon exhausted in childhood, and in promoting the healthy growth and vigour of the infant frame.

During the first epoch of infant life, the child should sleep with its mother, both for her convenience and its own comfort; but afterwards it ought to sleep in a crib or small bed by itself; and it ought on no account to be allowed to sleep with an old person, or one in ill health. The sleeping-room should be as large and airy as possible, comfortably warm, and free from draughts; and to permit the free access of air, the child's bed should have no curtains.

Children ought to be sent to sleep early; seven o'clock, or half-past seven, being the latest they should be allowed to be out of bed, till they reach the age of eight years. From that period till about the fourteenth year, they ought to be asleep by half-past eight, or nine o'clock at latest. Nothing is more liable to retard the growth, to injure the health, to expend the vital energies, to produce a weak, worn-out, and ghastly aspect, and to encourage indolent and irregular habits, than late hours for children and young persons. There is both sound common sense and true philosophy in the old proverb, "*Early to bed, early to rise, is the way to be healthy, wealthy, and wise.*"

Air and Exercise.—If there is one point more than another in which the fashions and customs of the greater portion of the middle and upper classes of this country, are utterly at variance with the precepts of nature and the laws of physiology, it is in the amount and manner of exercise which they allow their children, and more particularly their girls, from two to fourteen years of age. For the first few years of infant life, they are confined for the greater portion of the day to the nursery, and when they are sent out for air and exercise, they are not permitted to use their limbs, but carried out in the nurse's arms, with their legs and under part of the body squeezed together, and their feet, arms, and hands often chilled with cold. Dressed out in all their showy finery, which is much more thought of and more prized than strength of limb and vigour of muscle, their exercise for the next three or four years is a regular soldier-like march or drill, on a straight road, once or twice a-day, with toes out, back and shoulders straight, head erect, no allowance to move to this side or that, and if they dare jump aside and tumble on the grass, or kneel down and pick flowers, they incur the heavy displeasure of the mother and nurse for being so naughty as to spoil their very pretty and very becoming dress!

While yet mere infants, at the age of four or five years, they are eonfined in the school-room or sent out to school, the great object being to make them prodigies of learning—little old men and little old women. These schools, and particularly infant schools, are quite misnamed; they ought rather to be ealled *infant prisons;* they are indeed worse than prisons: by the system of teaching practised in them, not only are the mental faculties of infants and children urged to premature activity, at the expense of the healthy growth, of the future strength, and of the robust vigour of the body, but these very faculties themselves are cramped and checked in their development, the minds of the poor victims are overtasked and get confused, an innate hatred and dread of books take deep root, so that their chance of displaying even a mediocrity of talent in mature years is but very small.

In these respects the children of the poor, during the earlier years of their existence, are placed in much more favourable circumstances than the children of their richer neighbours. With no fine clothes to spoil, no rigid rules of discipline to adhere to, no capricious nurse to interfere with them, they are allowed to choose the mode and amount of their exercise,

* Dr. Fleetwood Churchill on the Diseases of Children.
† Dr. Underwood on Diseases of Children.

perfectly free and unrestrained: in fine weather, they almost live in the open air, running and playing about from morning to night; in cold or wet, however, they run the risk of suffering from exposure to these powerful causes of disease. But as to their moral and educational management, the children of the poor are in much worse position than the children of the middle and upper classes; they are sent to school at even an earlier age, not for the purpose of making them learned parrots like the others, but, as a matter of convenience to the parents, to keep them out of the way; they are therefore subjected to the same unfortunate treatment—a system of cramming their minds and cramping their intellects, of enfeebling their bodies and arresting their growth. There is scarcely an instance on record of a precocious child ever having been distinguished for superior talents in after-life. Men of the greatest genius have been generally noted for their dullness and stupidity during their childhood; the cause being that they are possessed of deep reasoning powers, but are deficient in quickness of perception, which is the quality that enables a child to gratify its parents by a display of superior talent while yet a mere infant. But an over-cultivation of the perceptive faculties checks the development of the reasoning powers, and the boy who displays a quick perception is liable to have his brain overtasked, and his mental powers overstrained; he shows a great aptitude for learning, and will perhaps appear as far advanced at the age of six or seven, as his duller brother will be, several years older. This dull brother, however, quietly observes and reflects on everything around him; he thinks and reasons within himself, whereas the quick boy learns like a parrot to be the creature of imitation; he will rarely ever display much originality; he can do nothing but what he has been taught.

A child, from two to ten years of age, will be in perpetual motion during its waking hours; and if it keep at all within the bounds of moderation, its exercise ought not to be interfered with; it cannot be too much in the open air, as long as there is no danger from cold or wet; and it will rarely carry its exercise to the extent of over-fatigue, if left to the freedom of its own will. For delicate and sickly children, who are unable to take a sufficient amount of exercise on foot, pony exercise will be an excellent substitute when it can be afforded; and when this cannot be done, exercise in a swing for an hour or two a-day will be found to be very beneficial to weakly children.

The exercises of children should be free and unrestrained—no tight clothing to interfere with the motions of all parts of the body—no tight-fitting shoes to cramp and distort the feet—and no rigid attention to rules of walking, such as keeping the step, turning out the toes, holding up the head, &c.; if we wish to rear a well-developed race and a healthy offspring, we must allow our children the liberty of scampering about in the green fields, or in some proper playground, with the utmost freedom, and even at the risk of occasionally making a mess of themselves.

But the most urgent and important caution which we would give to parents, is to beware of overtasking the brain while yet in a state of great softness, fulness of blood, and rapid growth; it would be equally reasonable to expect a child to lift heavy burdens with its arms, as to expect it to be able to suffer even a moderate amount of mental application, (which solely consists in the exercise of the brain,) without the most imminent risk of permanent injury. A child ought not to begin its letters till the age of five years; and even then merely as a play. It ought not to be sent to school till it reach the sixth or seventh year. Its confinement in school, during the first year, ought not to exceed two or at most three hours a-day; during the second year, three or four hours; four hours a-day ought not to be exceeded till the twelfth year is reached; and it ought to have a considerable interval of relaxation in the middle of every day. Were such a plan adopted during the education of youth, a "*mens sana in corpore sano*," (a vigorous intellect in a vigorous body,) would not be such a rare commodity; six months' education conducted upon proper principles, after eight years of age, would be of more value than three years' infant mental drudgery—for it is not education—carried on in the common way, and that too with infinitely less detriment to the health of the child. A moderately lengthened confinement to a sitting posture in school, with no support to their backs, and when their weak and soft muscles are worn out with fatigue, is absolute murder to children and young people; their bodies get crooked; their limbs become soft and emaciated; girls get curvature of the spine; and all to a greater or less extent suffer permanent injury. "Children have an ardent curiosity, a most retentive memory, and a strong propensity to, as well as a great power of, imitation. These circumstances prevent their being capable of patient attention to one object for any length of time, and explain the perpetual restlessness, levity, and caprice, which form the characteristics of that age. In regulating the exercise of the mind and body, these natural dispositions should be invariably kept in view. It may be truly said, that many facts relating to mechanics and to natural history may be communicated with advantage to young children. It is easy, therefore, to contrive a variety of occupation for their minds, and at the same time to afford them a good deal of bodily exercise in the open air, without allowing them to acquire those habits of idleness and of sauntering, which are sometimes with so much difficulty eradicated."*

DISEASES INCIDENT TO CHILDHOOD AND YOUTH.—This epoch of life contrasts very favourably with the period of infancy, in regard to the liability of the child to be affected with disease. After the dangers of teething are over, the child ought to be a very picture of health and happiness. It is true that disorders will arise which can neither be foreseen nor prevented, and it is also true that no preventative measures are yet known which can shield a child from the infection of measles, scarlet fever, hooping-cough, or even from modified small-pox;† still, if the constitution of the child be in a sound state; if it has not been deprived of the enjoyment of a sufficient quantity of wholesome food, of active exercise in a pure atmosphere, and of sleeping alone in a large, well-ventilated apartment, where not more than two others sleep; if it has not been exposed to wet and cold, and, in short, if the general management above recommended has been adopted, its chance either of escaping disease altogether, or of getting safely through most of those diseases which are the cause of so much anxiety and dread to parents, will be very great indeed.

No parent can absolutely change the constitution of his child; if it be naturally weak, or vitiated by hereditary taint, its condition of body may be greatly ameliorated, but can never be thoroughly changed. Notwithstanding the truth of this statement, however, the amount of health and disease which falls to the lot of most children is very much in their parents' own hands. We do not hesitate boldly to assert, that it will in a great degree depend on the treatment of a child by its parents, whether it will reach maturity or not, and whether, having arrived at maturity, it will have a constitution capable of sustaining the body in a sound state of health through the "*wear and tear*" of active life. By the treatment of a child by its parents, we do not mean *medical* treatment, but the adoption of the general rules of management above laid down; the less medical treatment or administration of drugs they get, the better. Nothing has a more powerful effect in weakening the constitutions of children and in producing disease, than the practice which some parents have of constantly dabbling amongst drugs; they dose their unfortunate children with purgatives, for no better reason than because some time has elapsed since they have had any, or because they erroneously suppose that their blood requires to be purified; they dose them with carmina-

* Dr. Hamilton on the Management of Children.

† Although *vaccination* has, unquestionably, the merit of saving the lives of thousands, and tens of thousands, of children annually, who would have fallen a prey to virulent small-pox, but for the discovery of the immortal Jenner; still, its warmest advocates do not claim for it the merit of being an effectual preventative of small-pox, but merely of in *most* cases very greatly modifying, and in *many* cases of preventing the disease. No parent can therefore neglect the use of it in the child, without incurring the highest degree of culpability.

tives, such as Dalby's Carminative, or some other trash, because they are troubled with flatulence, forgetting that flatulence arises from indigestion, and no carminative on earth can do more than produce temporary relief—most of them, indeed, do much harm; they, or the nurses by stealth, dose them with sedatives, such as Godfrey's Cordial, or some other slow poison, when the children are fretful, perhaps from teething, and are unwilling to go to sleep. All medicine, and particularly calomel, which is so great a favourite with mothers and nurses from its tasteless property, ought to be banished for ever from the nursery, except a little castor-oil, with perhaps a little rhubarb and magnesia. If a child is at all well, it ought never to taste medicine of any sort; and even if it be slightly indisposed, the simplest means should first be tried, such as restricted diet, light food, warm bath, change of air, &c., for it would not be more irrational to apply leeches or a blister to any part of the body where no pain nor the least disease existed, than to administer medicine of any sort, and particularly purgatives, to a child in perfect health.

The constitutions of children, as well as of grown-up persons, are as varied as the expression of their countenances. No two constitutions, even of those belonging to the same family, are exactly alike. One child will be of a costive habit of body, having its bowels opened only once a-day, and a day will now and then even be passed without a single stool; while another child will have its bowels opened regularly twice or three times every day—both these children, at the same time, continuing in the most perfect health. One child has what may be called a *gross* appetite; it is not particular as to what it eats, if it only get sufficient quantity; its stomach seems to digest anything; while a brother or sister has a small appetite and a weak digestion, the stomach becoming quickly disordered if it get anything but the most digestible food, and that too in limited quantity. One child again, and generally the one with the good appetite, is of a restless, active disposition; it is never happy but when romping about, or engaged at some active employment; while its brother or sister, with the weak appetite, is of a quiet sedentary disposition, dislikes being disturbed by the noisy sister, does not seem to require much exercise, and is easily amused with trifles. In short, the variety of constitution and of disposition amongst children is endless; and it would be no less utterly impossible to effect, than madness to attempt, the assimilation of these different and various constitutions and habits of body, by the use of purgatives, or any medical treatment whatever; *as long as the child is in tolerable health, the administration of medicines is most pernicious.*

Our next chapter will be occupied in describing the chief diseases incident to childhood and youth, in detailing their different symptoms, their causes, and the domestic treatment applicable to each; but as the great aim and object of this treatise is *not* to teach "every man to be his own doctor" or his child's doctor, *but* to instruct those who have their vision undimmed by the mists of prejudice, how to escape disease and avoid the necessity of doctoring, our remarks on these heads will on that account be very brief. It would, indeed, be infinitely more easy for a man to be "his own lawyer" or "his own parson," than his own or his child's doctor; he could study these professions, and no obstacle might stand in the way of his pronouncing a tolerably clear opinion on any given point; but it is totally different with the practice of medicine: when a person becomes affected with any sickness or disease, his mind participates in the ailment; when his child is taken ill, his feelings participate in its ailment; in neither case is his judgment clear and unclouded, *so that even a medical man, much less a non-medical, is totally unfit to be his own or his child's doctor.*

From these considerations, as well as from many others which our space here does not permit us to touch upon, we have no hesitation in saying, that it would not be a greater act of madness to embark on a voyage in a ship without a rudder, or trust her to the guidance of a landsman who knows nothing either of the sea, of the effect of winds, &c., on the ship's motion, or of the various rocks and shoals which may lie in her path, than to trust to the advice of our first chance visitor, or indeed of any visitor, to be guided by the empirical advice of a prescribing druggist or any other quack, or even to depend on our own skill and judgment, when we ourselves or our families fall a prey to disease.

HORTICULTURE.

CHAPTER VI.

THE PRACTICAL MANAGEMENT OF VEGETABLES.

All sorts of garden crops are far better sown in drills than broadcast. By so doing, three very important advantages are obtained. In the first place, it is far easier to keep down the weeds in drilled crops; secondly, the stirring and pulverizing the ground are much more easily accomplished; and lastly, in a drilled crop there is no difficulty in preventing individual plants from being too close together, and from being in consequence starved, and consequently never attaining their full maturity. It may be laid down as a rule, then, that all kitchen vegetables, down to radishes and onions, should be sown in drills.

As a constant succession of crops is taken from a garden, all of which tend to deteriorate the soil, it is not only necessary that the garden be in good heart, but that it be kept so by an abundant supply of manure. It may be put down as an axiom, that in good gardening there should be manuring for every crop. Sometimes, indeed, it is proper to give one crop a double manuring, and the next that follows it none. The plants that require such a treatment will immediately be noticed. The manure commonly employed in gardens is either ordinary farm-yard manure, or stable litter. But the portable manures used by farmers, such as bone-dust and guano, are too much neglected by gardeners. The good effect of a liberal dose of bone-dust to the soil of an exhausted garden is very great.

All drills should, as a rule, be made to run north and south, so as to give to each plant in them the same amount of exposure to the sun. If this be neglected, the chance is that the crop will come to maturity so irregularly, as, when things are managed on a small scale, not to furnish sufficient at a time for a dish. But, as sometimes is the case, if a small garden, only one crop—as of broad beans, for example—is planted, it is better to sow in a little additional quantity, and to make the drills not run north and south. By this the supply may be made to last over a very considerable period.

Every weed should be eradicated the day it makes its appearance. This not only prevents it from propagating, but increases, and to a considerable extent, the amount of vegetable produce obtained. A certain area of the garden will grow a certain amount of vegetables. If peas, for example, are grown upon it, and nothing else, all the amount of vegetation will be peas. But if two-thirds of it are cropped with peas and the remaining third with weeds, one-third less peas will be obtained.

The ground between the drills, when the plants are young, and the roots do not extend far from the centre of the drill, can scarcely be too much stirred. The reason of the good results that follow this process is, that air and moisture are admitted to the different particles of earth. This promotes the union of the elements of which the soil is composed, in such a manner as to become suited to supply the plant more readily with food.

Too little attention is paid to watering vegetables, particularly when they are young, and their roots small and superficial. A young plant, during drought, not only, by making little or no progress, loses time, but it acquires a sickly, diminutive habit of structure, and never produces the return which it otherwise would have done. Plants should not be watered during heat and strong light, as, under such circumstances, the cold produced by the great evaporation that takes place is greater than the good which the supply of water does. The holes in the rose of most watering-cans are too large; and when this is the case, the water falls in such large drops as to batter the surface of the ground, and form a crust so hard as to prevent the access of air and moisture to the soil.

Crops that attain no great height, and come rapidly to maturity, may be sown between the drills of young peas, beans, &c. In this manner, mustard, cress, lettuce, radishes, and spinach may be grown. But any one following this practice must remember, that even these small crops take so much from the ground, and that, to keep up the fertility of the soil, he must restore it in the shape of manure.

Having made these general observations, we proceed to the management of each individual vegetable.

PEAS.

It is common to sow a crop of peas in November, in the hope of having an early crop. A part of the garden, where the soil is light, dry, and sheltered, should be chosen for this purpose. As a general rule, the soil where peas are planted should have been manured for the previous crop, as the presence of undecomposed manure is believed to cause the pea to produce an excess of stalk, and therefore a deficiency of pods. The drills for this early crop should be an inch and a half deep, and they may be made about a yard asunder. The kind selected should be the Prince Albert, and a pint of seed should plant a row twenty yards long. One or more similar sowings may be made in February.

From February to the end of May, the main crops of Prussian blues and Imperial greens should be sown; and to insure a continuous supply, it will be necessary to have a sowing about once in three weeks. The drills for these should be made about two inches deep and five feet asunder, and one pint of seed is sufficient for a row of thirty yards and more.

After the end of May, the Prince Albert peas may be sown at intervals until the end of July, in the same manner as for the earliest crops.

It is common to soak peas in water for a few hours before sowing them, to hasten their germination.

Always after the peas are covered in in the drills, a few baited mouse-traps should be placed near them, as garden mice are very apt to scratch down to the seed, and eat it. Means must be taken, too, to prevent the ravages of birds.

When the young plants have attained the height of an inch, they must be earthed up, and this must be repeated from time to time, always selecting dry weather for the operation. The earth between the young plants should also be loosened, and weeds cut down. When the young plants have attained a height of about six inches, it is time to stick them. These sticks should be five or six feet high, and have a good many branches on. Each row of peas has a row of sticks, but some of the sticks should be placed before the peas, and some behind.

The early crops should be protected from the frost, by being covered at night with straw and the like, and after April, if the weather be dry, the peas must be watered. The late crop will almost infallibly require watering; and if this precaution be neglected, they will be ruined by mildew.

The early crops are gathered, at least at first, when the peas are very young, but afterwards they should be allowed to reach their full size; and a few of the earlier ones should not be gathered at all, but allowed to ripen, as doing this is found to make the crop bear for a longer time.

BEANS.

A few early long pods are sown in October in a sheltered place, in rows two feet asunder, and the beans three inches apart from one another; they should be about two inches deep. A still better plan to obtain an early crop is to sow them thickly together in a bed of light earth, in a warm situation, and protected during severe weather by some contrivance of straw, bushes, &c. When spring comes (March) they must be transplanted, and placed in rows two feet apart. In February, the main crops are begun to be sown. First, a crop of long pods may be sown at the distance above mentioned, then one of Mazagan, and then one of Windsor. These two last should be planted two and a half feet apart. Successional crops of these may be sown until the end of June, when another sowing of long pods may be put in; or a number of the beans sown in March, may, when they are in flower, be cut down. Fresh stems will arise from these, and produce beans very late in the season.

When the young plants are three or four inches high, they should be earthed up; and this process, and keeping them free from weeds, repeated from time to time. When they come into full blossom, many gardeners pinch off the tops, with a view of making them pod better. It is very doubtful, however, if this has any such effect.

Beans should be gathered before they have attained their full size, and the pods should not be twisted off, but cut with a knife or pair of scissors.

KIDNEY BEANS.

Kidney beans do best on a light dry soil, which has been well manured for the previous crop, but which has had no fresh manure added to it.

An early crop of Dutch dwarfs may be sown in the middle of April. The drills should be two feet apart, an inch and a half deep, and the beans one or two inches asunder. From May till the end of July, successional crops of the purple-spotted, in somewhat wider drills, and the seed not so close, may be put into the ground. At the beginning of August, a late crop of Dutch dwarfs may be tried, although it will probably be destroyed by the frost. If the ground at the time of sowing be dry, the beans should be soaked for a few hours in water.

The after culture consists in earthing them up, and keeping them clear of weeds.

The pods should be gathered when they are young and tender.

SCARLET RUNNERS.

There is little use in sowing scarlet runners until the middle of May. The seed should be sown in drills four feet asunder, and about two inches deep. The seeds should be about three inches apart from one another. When the plants have attained a height of about three inches, the earth should be drawn up around them, and sticks or poles about nine feet high put into the ground behind and before them, for them to climb up.

The after culture and gathering of the pods is the same as those of the kidney bean.

THE ONION.

The soil cannot be too rich for onions, and a large quantity of very rotten dung should be intimately mixed with it. But due care must be taken that the manure really is well decomposed. The usual plan is to sow onion seed broadcast, and, for a bed of twenty-four feet long and five broad, from one to two ounces of seed will be necessary.

But it is far better to cultivate onions in drills about eight inches apart. These should be made about the beginning or middle of March. In about three weeks the young onions make their appearance. They must be carefully weeded and thinned from time to time, until those that are left are about six inches apart. In September, they will probably have attained their full growth, and their leaves and stalks will fall down. They should then be pulled up on a dry day, and spread in the house. (For the mode of preserving them, see next chapter.)

In September, or in August, a second sowing is made to supply young onions in spring. The Strasburg is the best variety for this purpose.

The silver-skinned onion, for pickling purposes, should be sown in March, and perhaps they may be better sown broadcast.

THE LEEK.

Leek seed (an ounce will produce a great many plants) should be sown in March, and the young plants kept carefully clear of weeds. In the month of June, a portion of them must be transplanted into very rich ground, placed in drills fifteen inches apart, the plants being about six inches from one another in the drills. A large deep hole is made with the dibble, the top and root a little shortened, and then the plant is put in. The earth is scarcely closed over the plant. The remaining leeks from the seed-leek must be transplanted a month later.

By winter they will be ready for use, and will afford a supply until spring.

CHIVES.

The chive is a perennial plant, and a few of the roots should be planted on a bed, a few inches apart from one another. In a very short time the whole will have grown as close as grass. A new bed should be made every four or five years.

GARLIC.

The cloves of garlic should be planted in light but rich soil, in drills a foot apart, and the cloves about nine inches distant from one another in the drills. Each clove should be about three inches deep. The operation should be done in March.

The after culture consists merely in keeping the crop free of weeds.

The garlic is known to be ready for lifting when the tops begin to decay.

ESCHALOTS OR SHALLOTS.

A piece of rich ground should be chosen for the eschalots, and a thick layer of soot spread upon it. This should then be dug in.

The cloves of the eschalots are then planted in drills a few inches apart. This is done either in February or in October. By July, the withering tops will indicate that the crop has come to maturity.

ROCAMBOLE.

Either the cloves of the root or the cloves of the head are planted in rich ground, in drills similar to garlic, and this is done either in autumn or early spring. It attains its full size about August.

POTATO ONION.

Its culture is the same as that of the garlic, its bulbs being used as the cloves of garlic.

POTATO.

Growing late potatoes is every year becoming more and more the business of the farmer, and less that of the gardener. Still they are grown in gardens. Before, however, noticing their culture, we will describe that of early potatoes.

The ground in which they are intended to be planted is well spread with manure, which is then dug in. In the case of the earliest potatoes, the ash-leaved kidney and the Hopeton, it is better to use whole tubers for seed. If possible, for these a light soil and a warm southern exposure should be chosen. It is considered advisable by some to place a wet cloth around the potatoes intended for seed, and keep them in a warm room until they begin to vegetate, before planting them. Whether this be done or not, the seed potatoes should be placed in the ground in the beginning of March, and planted in drills a foot and a half apart, each potato being about eight inches distant from one another in the drill. The sprouts or eyes should be placed uppermost. As soon as the young plants are discernible, they must be carefully but deeply hoed, and this operation repeated in about a fortnight, and at this time the earth must be well drawn up about them. This crop must be protected from the frost by straw, &c.

Two more crops of these early sorts may be planted out in the course of the same month (March).

In the beginning of April, a sufficient quantity of American earlies and fortyfolds should be planted. There is no occasion to plant whole tubers of these for seed, but slices are made, each of which includes one or two eyes. The drills for these kinds should be about two feet apart, and the cuttings ten inches from one another in the drill. Both these kinds must have a large quantity of manure, and the latter in particular.

The after culture of these two kinds consists in hoeing, keeping down weeds, and earthing up.

A little later (the second week of April say) the regents should be planted. Their management is the same as that of the two last mentioned, save that the drills should be twenty-seven inches apart.

If late potatoes are grown in the garden, cups and Orkney reds may be fixed upon. They should be planted in drills, at least twenty-seven, and, perhaps preferably, thirty inches apart, and it is common not to dig the manure for them into the ground, but to distribute it in the drill. The propriety of this, however, may be doubted. The sets in the drills should be at least a foot apart.

Some gardeners are in the habit of pinching off the blossoms of the late kinds, and believe that by so doing they promote the increase of the number of tubers.

The early potatoes are ready for lifting, or use, when their skin easily rubs off, and the late ones when the haulms begin to decay. For the modes of storing and preserving these latter, we refer to the next chapter.

It may be laid down that land, on which it is intended to grow potatoes, should receive at least five cart-loads of manure to the rood, and, with respect to the later ones, this quantity may, with advantage, often be doubled.

JERUSALEM ARTICHOKES.

This vegetable is propagated by planting small tubers, or large ones cut into pieces. The drills should be made about twenty-seven inches apart, and the sets a foot distant from one another. As much manure must be applied as to the late potatoes. The after culture merely consists in keeping them clear of weeds. In the autumn the haulms decay, and then the tubers are ripe.

Jerusalem artichokes do better if planted as early as February.

TURNIPS.

These are now more a field crop than a garden one, but early and late kinds are still extensively grown by the gardener. The best kinds, as we have said, are early Dutch for an early and late crop, yellow Maltese to follow it, and, if a crop is raised for storing, Laing's Swede. The first of these may be sown in March, the Maltese in April, the Swede during the early part of May, more Maltese in June, and the Dutch at intervals from that time up to the end of August.

All should be put into well-manured land, and the manure is preferably put into the drills. These drills should, for the early kinds, be about a foot apart, and the plants thinned out in them to a distance of eight inches. The Swedes must be farther apart in every respect, and it is important to remember that Swedish turnips never succeed without a liberal allowance of manure.

Young turnips are very liable to be attacked and destroyed by an insect called the *Haltica nemorum*. If the young plant can get its second pair of leaves before the first pair is destroyed, it is generally safe. Hence the best mode of cure consists in placing the manure in the drills, so as to promote rapid vegetation during the early days of the plant.

Care must be taken not to bury the turnip seed too deep in the drills, otherwise the chances are that it never germinates.

CARROTS.

This vegetable flourishes best upon a light deep soil. Indeed, the orange variety cannot attain perfection unless the soil is nearly a foot and a half deep. Accordingly, if the soil of any particular garden have not this depth, it is better to use the Altringhams for the main crop.

The ground on which it is intended to grow carrots is better if manured the previous year. The early born should be planted in March, the main crop in April, and some more early born in June and July. This latter is necessary, because, particularly in old gardens, the main crop of carrots is often a complete failure.

It is common to rub a little sand amongst the carrot seeds, to prevent them sticking together. The drills should be about a foot (for the main crop a little more) apart. These must be made very shallow, the seed dropped into them, and then covered with a rake. As soon as they come up, they should be thinned out to the distance of three inches, the ground around them hoed, and kept free from weeds. As they are wanted, every alternate one should be drawn, and thus those left for the main crop will be at the distance of six inches.

The carrot is liable to two diseases. As soon as it has attained a very small size, it often, especially in old gardens, becomes yellow in its foliage, and, on pulling it, we find the

crown discoloured, and, if we then unfold the embryo leaves, we see the cause of the mischief in a number of pale-green little aphidæ, or mites. The other disease is called the rust, and attacks the roots. Carrots affected with this rust die off, and the roots, upon examination, are found to have acquired a ferruginous colour, and to have lost their saccharine principle. This is caused by the larvæ of the carrot-fly eating galleries through the roots. They then become pupa, a new brood, during summer, being hatched every three weeks. Mr. Curtis states that these insects might be prevented from thus attacking the carrots, by using a composition of sand and spirit of tar. He advises four bushels of the former and a gallon of the latter to be mixed together. This mixture should be applied over the drill, spreading it to the extent of about six inches. The quantity above specified will, used in this manner, extend over thirteen hundred yards.

Carrots are known to be ripe when they have attained their full size, and the leaves begin to decay.

PARSNIPS.

This vegetable is a striking instance of the effects of culture. It once was what the potato now is, and indeed something more. As far as our ancestors had winter vegetable food, the parsnip afforded that food, and our great-grandmothers used to prepare a wine from it, which is said to have been very good. We may be allowed to state our opinion, that the making of wine from native productions is far too little attended to in this country. At present, parsnips are little grown in this country, and when grown little esteemed. We believe that the reason of this latter is owing to their being lifted too soon. A parsnip is not good until it has been exposed to pretty severe frost.

The parsnip requires a deep soil, not recently manured; it should be sown in drills fifteen inches apart, and the plants thinned out to about ten inches distant from one another. The seed should be put into the ground by the end of March.

The roots attain their full size by the beginning of November, but should never be lifted until they have been exposed to a pretty smart frost.

RED BEET.

Beet requires the manure to have been well mixed, and to a great degree incorporated with the soil; and in order to obtain large plants, the soil must be deep. The mode of culture is to sow it in April, in drills fifteen inches apart, and to thin out the plants to about seven inches from one another. If it is desirable to do so, beet roots will transplant, although those so treated never attain the same size as the ones that are not removed.

Beet roots are ready for lifting by the month of October.

SKIRRET.

It is doubtful if this and the two succeeding vegetables are worthy of cultivation; however, we give the following brief account of the proper mode of managing them.

Skirret is sown in drills in the earlier part of April, the drills being eight inches apart. When the young plants have come up, they are thinned out to a distance of five or six inches asunder. They are fit for use before autumn.

SCORZONERA.

This vegetable should be sown in April, in drills a foot apart. The plants should be thinned a distance of six or eight inches. They are at maturity in autumn.

SALSIFY.

This may be sown in April, and treated like the last mentioned.

RADISHES.

Radishes may be sown every fortnight, from February to November. The salmon radish is the earliest, and may be sown first, and the Spanish, or hardiest, the last. In the interval between the first and the last sowing, the salmon radish and the turnip radish may be sown alternately.

Radishes are best sown in narrow drills, and thinned out as they come up. In dry weather, unless regularly watered, they will not succeed.

SPINACH.

Spinach is either sown between young peas, beans, cabbage, &c., or in beds by itself. In either case it should be sown in drills, and the richer the ground is the better. The drills should be about a foot apart, and two inches deep. When the plants have got three or four leaves, they should be thinned out to three inches apart, and well cleared of weeds; and in about three weeks after this, they should be again thinned out to six inches apart.

Plenty of manure and due attention to thinning, are the two great secrets of rearing good crops of spinach.

The first sowing is made in August, another in February, a third in March, and then one every fortnight or three weeks until August. In summer, these frequent sowings are necessary, because summer-sown spinach has a strong tendency to run to seed.

WHITE BEET.

The culture of this is mainly the same as that of red beet—(which see.)

ORACHE.

"The orache is raised from seeds which should be sown in a deep rich soil in August or September: sow in drills from one foot to eighteen inches asunder; keep the ground clear of weeds during the autumn, and in spring thin the plants to four or six inches in the row. Stir the soil occasionally till the plants come into flower in July, when the crop may be considered over. Spring sowings, however, are made in places where this sort of spinach is in demand."

NEW ZEALAND SPINAGE.

For the management of this, see Chap. IX.: "The management of hotbeds and hotbed plants."

SORREL.

The best mode of propagating sorrel, is by parting the roots in spring or autumn. These require pretty good soil. They have a great tendency to run to seed. To obviate this the stalk should be cut down, and a little mould thrown over the stool. They should be kept clear of weeds, and the earth about them stirred every autumn and spring.

KAIL.

Scotch kail and German greens are sown broadcast at various times from February to May. For a bed of two feet by five, about half an ounce of seed is necessary. The young plants are transplanted during summer and the early part of autumn.

They should be placed in well-manured ground, in rows two feet asunder. The after management of them consists in keeping the ground free of weeds, and in hoeing about them. If convenient, damp weather should be selected for planting them; and if this cannot be managed, plenty of water must be poured around the newly-transplanted plants.

BRUSSELS SPROUTS.

The seed should be sown at twice in the spring, and the seedlings transplanted out if possible also during damp weather, at various times, beginning with June. In October, the earth should be well drawn about their roots. They may be planted as near as eighteen inches every way to one another.

RED CABBAGE.

Two sowings of red cabbage seed should be made—one in August, and another in spring. The seedlings of the first are planted out early in spring, and those of the latter in June. If the large variety is grown, the plants should be put, of course, wider apart than those of the smaller. The after culture consists merely of keeping away weeds, and occasionally stirring the ground.

WHITE CABBAGES.

M'Ewan's should be sown about the middle of August, planted out in rows in October, and in February placed in the ground in which they are meant to heart (and which must be well manured), in rows twenty-seven inches apart. Early dwarfs may be treated in the same manner, or the first transplantation of them may be omitted. The Yorks should be sown

in the beginning of March, and planted out in May and June, and the drumheads may be sown and planted a little later.

In dry weather, cabbages should be watered both to supply the plants with water, and to wash off the numerous aphidæ that prey upon the cabbage.

CAULIFLOWERS AND BROCCOLI.

The following is the practice relative to these vegetables:—Cauliflower seed is sown about the middle of August, pricked out thickly in the ground in the warmest part of the garden, and protected from the cold by matting, hand-glasses, &c. In May they are planted out in rich ground, in rows similar to cabbages. More cauliflower seed is sown in May, and the young plants placed in the ground in which they are to flower, as soon as they are big enough.

Broccoli seed is sown in March or April, and planted out when large enough. The plants stand the winter very well, and flower in March, April, and May, of the following year.

After cauliflower and broccoli plants are planted out, all the culture they require consists in earthing up the ground around their stems.

ASPARAGUS.

Upon the whole, perhaps the most convenient method of growing asparagus is as follows:—

An asparagus bed is generally made four feet wide. If the ground will admit of it, it should be trenched to the depth of a yard, and it must be so done to the depth of at least two feet. If near the sea, a quantity of seaweed should be procured, mixed with manure and spread upon the bottom. If seaweed cannot be got, manure alone must be used. This manure should be nearly a foot in thickness. The earth is then thrown upon it. Upon the top of this, a good quantity more manure should be spread and dug in. An alley should be made on each side, and the earth from them thrown upon the asparagus bed. What with this earth and the manure, the bed will be higher than the rest of the garden. This is desirable, as it will be always dry, and nothing is so injurious to asparagus as moisture.

A sufficient number of two-year-old plants should then be bought from a seedsman. This may be done in March or April. They must be exposed to the air as little as possible, and planted with all despatch. They are planted in rows, the rows being a foot apart, and the plants at nine inches distant from one another in the rows. The plants should be completely buried.

The plants soon come up and flower. During the summer, all that is necessary to be done, is to keep the bed clear of weeds. By autumn the flower-stalks are dead. The ground should then be very gently stirred with a fork, and a layer of manure thrown over it, and over this a little earth.

Next year a very few of the asparagus may be used, but the year after they may be freely taken. Still, if they are too freely taken, the plants become degenerate and small. Hence the old-fashioned plan, of never cutting asparagus after peas come in, is a very good one.

After the bed is fairly established, it merely requires weeding in summer, and the layer of manure and earth in autumn.

It is now common to grow asparagus, not in beds, but in rows three or four feet asunder.

If desired, the plants can be raised from seeds; but this puts off another year, and the plants can be obtained, upon very reasonable terms, from the seedsman.

SEA-KAIL.

Beds four feet wide should be prepared in the same manner as asparagus beds. Sea-kail plants are bought from the seedsman, and two rows of them planted along the bed, and about two feet and a half from each other. The plants soon send out beautiful leaves, and all that is required is to keep them free of weeds.

At the end of autumn the stalks are cut over, and the decayed leaves removed. The ground is a little loosened about the plants, and around each plant a thin stratum of coal ashes is laid, to hinder the earthworms from harbouring there. A pot, with a movable top, is then placed over each plant; and around all these, stable litter is placed. In the course of six weeks, the shoots of many of the plants will be ready for cutting, and will be perfectly blanched. By putting on the litter at different times, a supply may easily be obtained from December to May.

Every two pots will furnish three moderate-sized dishes.

ARTICHOKE.

The artichoke is propagated by young shoots that spring from the roots of the old plants. These should be slipped off in the beginning of April, when they are about eight inches high.

The ground for the artichokes should be well manured, and the slips placed in rows at four feet distant, and apart from one another in the rows two feet. They should then be watered every day until they take root.

In autumn the decayed leaves should be removed, and the ground well dug and manured. A quantity of straw should be twisted round the base of the leaves, to protect the plants from the frost. In spring this is removed, the stalks are examined, and about three of the strongest left to produce heads. The ground is then dug, and again manured. A supply of heads should be procured from June to November.

CARDOON.

The following is Neill's account of the culture of this plant: "Cardoons are found to prosper best on light deep soil. The seed is sown annually in the middle of May, in shallow trenches, like those for celery, and the plants are thinned out to ten or twelve inches from one another in the lines. In dry weather, water is copiously supplied, not only to increase the succulence of the leaves, but to prevent the formation of flower-stalks, which render the plants useless. In autumn, the leaves are applied close to each other, and wrapped round with bands of hay or straw, the points of the leaves only being left free. Earth is then drawn up around the leaf stems, to the height of fifteen or eighteen inches. Sometimes cardoons are blanched by a more thorough earthing up in the manner of celery, but in this case the operation must be commenced in summer, and regularly carried on through the autumn. During severe frost, the tips of the leaves should be defended with straw or haulm."

RAMPION.

Rampion seed should be sown in narrow drills at the end of July, and the seed should have been produced the same year. When the plants come up, they should be thinned to a distance of three or four inches. Before the frosts begin, the roots should be taken up and stored in sand.

LETTUCE.

Lettuces are sown broadcast, and then transplanted. The first sowing may be made in February, and successively every month until August, when the black-seeded may be planted for a winter supply.

Cabbage lettuces should have a piece of matting tied around the top of the leaves to blanch them.

ENDIVE.

This is a winter salad. A sowing of the white-curled kind may be made in June, and of the green-curled in July. When big enough, the young plants are transplanted into rich soil, and placed fifteen inches asunder.

When the plants have arrived at maturity, their leaves should be gathered up, and tied together a little below their tips, in order to blanch them.

CHICORY.

Chicory is sown in May in drills, and thinned out to a distance of four inches. In August they are cut down to within an inch of the ground, to prevent their forming flower-stalks. In October they are lifted, the large leaves cut off, and the roots shortened, and the plants are put into boxes filled with mould. As they are wanted in the winter, a box is put into a cellar, where they soon become blanched. Two crops are obtained from each plant.

CELERY.

In the month of March, and again in April, the seed is sown upon little seed-beds. Towards the end of May, trenches are prepared, into which the young plants may be transplanted for the purposes of attaining their full growth, and of being

blanched. Celery trenches should be made about an inch apart, should be fifteen inches wide, and the earth should be thrown out of them to the depth of at least a foot. The soil at the bottom of the trench must now be dug and very well manured, and perhaps the best manure for the purpose is that from a poultry-house or dovecot. The plants of the celery are then pricked out in a single row, in the middle of the trench, the plants being at four or five inches apart. When the plants have been thus put in, a most liberal supply of water is indispensable, and if the weather keeps dry, this watering must be repeated from time to time. When the plants have attained the height of about a foot, the earth must be heaped around their stalks, taking care that none gets into the heart of the plant. From time to time a little more earth may be added, and the presence of the earth around the stalks effectually blanches them.

MUSTARD AND CRESS.

These may be sown all the year round, save in midwinter. The mustard may be sown every month, and the cress every fortnight; or they may both be sown every fortnight, but double the quantity of cress must be used.

PARSLEY.

Parsley should be sown in drills in March. As the plants grow up, they are to be thinned out. In severe weather they should be protected by boughs of trees, &c.

TARRAGON.

Tarragon is propagated by dividing the roots in April, and planting them in a light rich soil.

FENNEL.

Fennel seeds are sown in spring, and the young plants transplanted to where they are to remain, when they are three or four inches high. They should be put about fifteen inches apart. A bed thus formed will last many years.

HORSERADISH.

Horseradish likes a cool shady situation. A piece of ground should be trenched, and, in the middle of March, cuttings of the root should be dibbled in about nine inches apart, and about fifteen deep. At first the young plants will require to be kept free of weeds, but they will soon acquire a sufficient magnitude to kill all weeds. A new bed ought to be made every two or three years.

INDIAN CRESS.

The seed is sown in April. When the young plants come up, they should be stalked.

MARIGOLD.

The seeds should be sown in April, and the young plants afterwards transplanted. They will then require no farther attention.

BORAGE.

Sow the seeds in April.

THYME.

Common thyme is raised from seed which must not be covered very deep. In two or three weeks the plants make their appearance, and when they have got full bushy heads, they should be transplanted to where they are intended to remain. They should be placed about six inches from one another, and well watered.

Lemon thyme is best propagated by parting the roots.

SAGE.

Sage is propagated by slips, which are taken off and planted in April. The after culture consists merely in weeding, and cutting down decayed flower-stalks.

CLARY.

Clary is raised from seed sown in March.

MINT.

Green mint is propagated by parting the roots in spring, and planting them in drills about a foot apart.

In order to have mint to be ready for making mint sauce to the early lamb, it is necessary to force two or three plants. This is done by burying a little bundle of fermenting stable litter in the ground towards the end of November, covering this with earth, and in it putting the mint plants. A garden light or matting, supported by hoops placed in the ground, should be placed over all except in the middle of the day, when the sun is shining.

Peppermint is propagated by cuttings, or by dividing the roots in spring.

MARJORAM.

The hot marjoram is easily propagated by parting the roots in spring, and planting them in any convenient place. One or two such partings will be quite sufficient for any ordinary garden.

SAVORY.

Savory requires to be raised from seeds every spring. There is, however, a perennial kind.

BASIL.

This is an annual plant, and, if grown at all, should be sown in the beginning of May.

ROSEMARY.

The common mode of propagating rosemary, is by means of slips or cuttings in the early spring months.

LAVENDER.

Lavender is easily increased by planting cuttings in the spring.

TANSY.

Tansy is propagated by parting the roots in spring, and planting them in one or more short drills. They do best upon a rather light soil.

RHUBARB.

Rhubarb is increased either by sowing the seeds, or by dividing the roots. The latter is by far the commoner practice. It requires a light but a very rich soil, and of all plants shows the most immediate return from the application of liquid manure. A portion of the rhubarb crop is allowed to come to maturity at its own unaided time, but a certain portion in all good gardens is forced. This is best done by knocking the ends out of an old cask, placing it over the plant, and surrounding it with fermenting stable litter.

GOURD AND VEGETABLE MARROWS.

See Chap. IX. On the management of hotbeds and hotbed plants.

ANGELICA.

Angelica is raised from seeds. Those ripened the same year should be chosen, and hence the sowing should not be made until the month of August. A moist situation should, if convenient, be chosen, and when the plants are six inches high, they should be transplanted into a similar part, and put about a yard apart. If the plants are prevented from running to seed by cutting down the flowering stems, they will last a number of years.

CARROWAY.

This is a biennial, and is propagated by sowing its seeds in spring.

CHAMOMILE.

The roots should be parted in spring, aud planted in rows about a foot apart.

RUE.

Rue is propagated by planting slips in the early spring months. These slips require for some time daily watering.

HYSSOP.

This, if considered desirable, is easily propagated by slips in spring.

ELECAMPANE.

This is propagated by offshoots in autumn, after the plant has done flowering.

BALM.

Balm is a perennial, and readily propagated, by parting the roots in spring or autumn.

TOMATO, EGG PLANTS, CUCUMBER, AND MUSHROOMS.

See Chap. IX. On the management of hotbeds and hotbed plants.

NATURAL PHILOSOPHY AND CHEMISTRY.

CHAPTER XXVII.

ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART II.—ELECTRO-MAGNETISM.—*(Conclusion.)*

77. OUR attention has hitherto been directed to the consideration of the action of voltaic currents on *magnetised* bodies, and of the latter on the former. We shall now inquire into the action of these currents upon *unmagnetised* bodies; in other words, the effect produced on *soft* iron, incapable of becoming a permanent magnet by an electric current.

78. The influence which produces the various magnetic phenomena in soft iron, is not *direct*, but *inductive;* not operating by the transit of a current along the soft iron itself, in its capacity of an electrical conductor, but by the transit of a current along a wire of copper, silver, or other metal, which surrounds the soft iron, either in one or many convolutions, and which disturbs the equilibrium of the electricity *naturally* attached to, or residing in the iron—producing currents within its mass—altering its molecular arrangement, and exciting *externally*, attractive and repulsive forces.

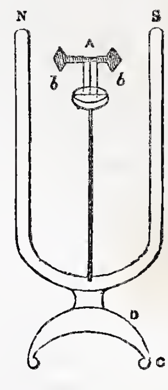
79. A piece of soft iron—no matter what may be its form—round which an electric current is made to circulate, is designated an electro-magnet; which, so long as the current is circulating, *but no longer*, possesses all the properties of a natural or an artificial steel magnet, but in a much greater degree, which degree may be increased or diminished by the number of convolutions of the conducting-wire; to this however, there is a certain limit, dependent upon certain laws, which we shall explain hereafter.

80. As a proof of the transverse attractive force of the voltaic current upon iron contiguous to it: if a thick copper wire be extended between the poles of a Voltaic battery in action, and some fine iron filings sifted thereon, they will be found to adhere to the wire and arrange themselves in bands passing transversely around the wire—the particles constituting each band adhering to one another by the force of magnetic attraction. In Sir H. Davy's experiments, the filings adhered to the wire connecting the poles of a voltaic apparatus, consisting of a hundred pairs of plates of four inches, in such considerable quantities as to form a mass round it ten or twelve times the thickness of the wire. Similarly, if a copper ribbon conducting the current, be held over a sheet of paper on which iron filings are scattered, the filings will be attracted by the ribbon, and arrange themselves in parallel lines at right angles to the direction of the current. The regularity of arrangement will be preserved so long as the current passes, if undisturbed by any external influence; but if a magnet be approached towards the ribbon, an immediate disturbance and change of arrangement takes place.

81. It follows from this transverse action of the current in developing magnetic properties in iron, that if *steel* in place of *iron* bars or needles, be subjected to the *same* influence, they will become *permanent* magnets, in all respects similar to steel magnets made by the common processes. It only becomes necessary to place them *across* the conducting wire either above or below, when it is desired that they should exhibit northern and southern polarity. If placed parallel to it, they will exhibit the same magnetic action as the wire, itself; and iron filings will attach themselves thereto in parallel transversal bands; but in the latter position, the needles will retain their magnetism only so long as the current passes.

82. It has been already observed (paragraph 72), that if a helix be suspended so as to be at liberty to assume any horizontal position, it will place itself in the magnetic meridian. Now, a helix containing within its convolutions a bundle of iron wires, or a cylindrical piece of soft iron, constitutes an electro-magnet, which, if similarly suspended, will also move into the magnetic meridian; and Professor Ritchie, by a very simple arrangement, produced *circular* motion in an electro-magnet so suspended or supported on a central pivot. The annexed figure represents this arrangement in its simplest form, various modifications of which, all dependent on the same principle, are now constructed by philosophical instrument makers.

In this figure, N, S, represent the north and south pole of a bent magnet, fixed to a stand C at D. A is the piece of soft iron, supported on a central point, and surrounded at its extremities by wire covered with silk or cotton, for the purpose of preventing the current passing laterally. This wire has its ends projecting, and these ends dip into the reservoir *b b*, containing mercury, and divided into two equal parts by an insulatory partition, which runs in a direct line between the two poles. This reservoir contains mercury, and each division is connected with one of the poles of the battery. Under these circumstances, when a current is transmitted, it passes into one of the divisions, and along the wire surrounding the soft iron into the other division, and thence to the battery. The result is, that when the current passes, the soft iron becomes an electro-magnet, one of whose poles is attached by one limb of the steel magnet, and the other pole by the other limb; but the impulse is so great that the poles of the electro-magnet move *beyond* the pole of the steel limbs, and thus produce a change of direction of the current through the wire, which causes that pole of the electro-magnet, *previously* attracted, to be now repelled; therefore the electro-magnet, in place of coming to rest in the magnetic meridian, or in a line between the two limbs of the magnet, proceeds onward, describing a circle, and changing the direction of the current at every half-revolution. This electro-magnet, when carefully constructed and slightly modified, may be made to rotate by the sole influence of *terrestrial* magnetism.



83. It has been found, that the intensity of the magnetic power, induced in soft iron, is proportioned to the quantity of electricity which passes along the wire in a given time, for which reason vitreous electricity, transmitted *directly* from the machine along the wire, produces no perceptible effect; but if the concentrated electricity of a Leyden battery be discharged through a wire surrounding a steel bar, magnetism will be induced in that bar, which will be permanent, and needles placed across a wire conducting such a concentrated current, will also become permanently magnetised.

84. It has been ascertained that bars of steel intended to be magnetised, when inserted in a glass tube, or other insulating body, and then placed in the axis of a helix, will be influenced equally by the passing current; and that if such bars be left within the helix for more than a few seconds, the polarity, first induced, becomes impaired, and in some cases is totally destroyed. It has also been found, that in order to induce double polarity, it is not necessary to introduce more than *half* the length of the bar or needle within the helix, inasmuch as that part of the steel which has acquired magnetic properties by the influence of the conducting-helix, communicates those properties to the external portion.

85. It is worthy of remark, that there appears to be a great difference between the effects of a Leyden battery discharged through a conducting-wire, and of a current emanating from a voltaic arrangement. In the former case, if the discharge be sent along a straight wire, needles of similar size, placed across that wire at certain distances from, and parallel to one another, will *not* be similarly polarised, some having *north*, and some *south* poles on the *same* side of the conducting-wire, while others are not polarised at all.

These variations appear to depend upon many causes, such as the intensity of the discharge, the thickness of the needles, length and diameter of conducting-wire, &c.; but it appears that the *thinner* the wire, the less subject are the needles to these variations, particularly where their coercive force is feeble. A constant voltaic current has not been found to produce such variable effects, the polarities generally being the *same* on the *same* side of the conducting-wire.

86. If a steel or iron bar be surrounded by a cylinder of copper, or silver, or other metallic conductor of electricity of a certain thickness, and be then placed within the helix, the magnetising influence of the current passing along that helix will be intercepted; but if the thickness of the metallic cylinder be reduced, the influence will become perceptible, and, when brought to a certain degree of thinness, the magnetic influence will be greater than it would be were there no cylinder interposed. In order to produce increased action, the intervening metallic cylinders must be extremely thin, for the action diminishes as the thickness is increased. It has been ascertained that metallic filings interposed, do not interfere; but that if alternate cylindrical layers of metallic and non-metallic bodies intervene, the magnetic influence is intercepted. It would appear, therefore, that diversity of molecular arrangement, and interruptions in the continuity of the intervening substances, in a direction at right angles to the axis, as well of the *bar* as of the surrounding *helix*, greatly influence the magnetising power of the traversing current. These remarks, of course, apply to the action of a discharge from a *Leyden* battery, not a *Voltaic* battery, and this action would appear to arise from the *suddenness* of the discharge, and the consequent sudden shock or impulse given to the particles, either directly in, or contiguous to, its course. The variation of polar state in needles placed transversely to the wire conducting the current, appears, however, to depend wholly on the intensity of the discharge—discharges of *different* intensities being found to produce *different* polarities at the *same* extremities of the *same* needles, in the same transverse positions.

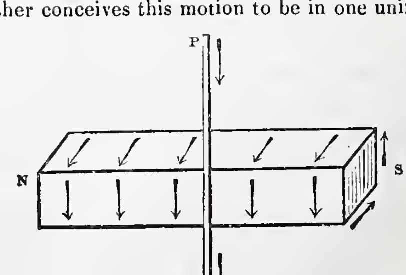
87. There are two applications of electro-magnetism which in this place deserve attention; namely, its application as a motive power, and its application to the production of shocks and decompositions. In the first, the magnetic force is developed by a current of voltaic electricity sent along a wire of medium thickness wound round a soft iron core, as nearly as possible at right angles to the *axis* of the core. Electro-magnets are constructed of various *forms*, but the principle in all is the same; however, the horse-shoe form, or some modification thereof, is generally that adopted by all who have applied electro-magnetism to the obtainment of locomotion; but as it is intended to give a detailed description hereafter, of the most successful magnetic arrangements, we shall not enter further into the subject in this place. In the construction of instruments for the application of electro-magnetism to production of shocks and decompositions, the arrangement of the magnets is not so simple; for, in this case, *two* sizes of wire are employed; the *larger*, which is contiguous to the soft iron core, (as in the *first* form), is intended to convey the current; and the *thinner* is wound round the larger, and is that employed to develop effects of intensity. In this wire, the electricity is developed by the *induction* of the current moving in the thick wire, and not by the passage through the thin wire of a current from the battery. Of the nature of this action we shall speak more fully when the subject of the mutual action of electric currents comes to be discussed; here, it will suffice to state that, according to the most accurate observations, the intensity of the current induced in the external helix depends, first, upon the *magnetic* power of the electro-magnet; secondly, on the *length* of the helix; thirdly, on the *thinness* of that helix; fourthly, on the inverse distance between the external helix and the iron core; fifthly, on the mode in which both wires are coiled on the soft iron; and lastly, on the perfection of the insulation of each coil of wire from the neighbouring coils.

88. The *magnetic* power of an electro-magnet appears to depend, first, on the weight of the soft iron core; secondly, on the quantity and intensity of the current which passes in a given time round the core; thirdly, on the inverse distance between the iron core and the current passing round it; fourthly, on the direction of the circulating current; and fifthly, on the degree of insulation of the wire conveying that current.

89. It may be well to observe here, that in the construction of electro-magnets, it becomes of the utmost importance to proportion the quantity and thickness of wire employed to conduct the current, to the mass and sectional area of the soft iron to be magnetised; and the dimensions and quantity of *both* to the number of alternations and size of the metallic plates of the battery employed; for, unless the electro-magnetic and voltaic elements be duly proportioned, the power of the battery may be unnecessarily great, or not sufficiently so—or the number of convolutions of the conducting wire may *not* be adequate to induce the greatest amount of magnetic force in the soft iron, or the mass of the soft iron may not be adequate to develop the force producible by the number of convolutions. The ignorance of experimenters upon these points, has too often led to unnecessary expenditure of materials, or to insufficient expenditure; and in *both* cases, to disappointment and erroneous inferences.

90. Although we are unwilling to direct the reader's attention to, or encourage his reliance upon, any of the prevailing theories of electricity, or electro-magnetism, in as much as we believe those theories to be inadequate to the satisfactory explanation of the various phenomena, and therefore to clog and misdirect the inquiries of the investigator; still, as there is *unusual* ingenuity in *Ampère's* theory, and as it explains a greater number of facts in *one* science, than modern theories generally do, we do not hesitate giving in this instance a general view of the theory in question.

91. It is usual to divide the phenomena connected with electro-magnetism into three classes, namely, the development of the tangential and rotatory force by the mutual action of a magnet and conducting body; the induction of magnetism by the conducting body in steel or iron, placed transversely to the direction of the current; and thirdly, the forces exercised upon each other, by two currents passing through *different* conductors. It has been customary to consider the *first* of the above facts to be the leading one, and the two others as deducible from it; but *Ampère* assumes the *third* to be the foundation upon which the other facts are all dependent. He denies the existence of a magnetic fluid distinct from electricity, and resolves all the phenomena into certain movements of electric currents around or amongst the particles of ferruginous bodies. According to his theory, every molecule of a magnet must be considered as surrounded by an electric atmosphere which is continually revolving round it, and the only difference between a piece of steel or bar of iron magnetised, and a piece *unmagnetised*, is, that in the latter the electricity is in equilibrium and at *rest*; whereas, in the former, it is *not* in equilibrium, but in a state of *rotatory motion*, the effect of which is developed in magnetic attraction or repulsion. He further conceives this motion to be in one uniform direction, in planes perpendicular to the axis of all bodies possessing magnetic properties, in which number the globe of the earth is included. Thus in the annexed figure, inasmuch



as the currents circulating round each particle contained in the magnet, N S, revolve in planes at right angles to the axis of the magnet, their action must be *transverse* to that axis, and must induce a straight conducting wire, P M, also into a *transverse* position in relation to the axis, and to the magnet itself, in which position the current traversing the wire is parallel to the direction of the currents in the adjoining part of the magnet. This explanation of transversal action is grounded chiefly upon the assumption which Ampère subsequently proved by experiment, that every electric current tends to induce currents in the same direction in other bodies.

92. This theory, however, although extremely ingenious, and affording satisfactory explanations of the greater number of the phenomena, has, unfortunately, *not* succeeded in removing the difficulties which are created by the extraordinary circumstances attending the induction of magnetism by electrical currents traversing conducting bodies, which have been particularly referred to in paragraph 85, and which were first noticed by Savary. No hypothesis has as yet been promulgated, which satisfactorily explains the strange variations alluded to.

93. This chapter concludes that part of the science to which the term "electro-magnetism" *strictly* applies, although it has been customary to include, under the same head, the subject of electro-dynamics, or the mutual actions of electric currents moving in different directions. It is, however, our opinion, that this latter subject would be best treated under a distinct head, and as a distinct branch of electrical science. It is proposed, therefore, to devote a few chapters to the subjects of electro-dynamics, and magnetic and thermo-electricity, including a description of those voltaic and electro-magnetic instruments which appear most useful in modern research, and are most likely to advance future discovery.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXIV.

OF THE ORGAN OF HEARING IN MAN—ITS ANATOMY, PHYSIOLOGY, AND PATHOLOGY.

No one unacquainted with the mysterious structures revealed to us by anatomy, would ever have imagined or conjectured the singular form, the high complexity, the inexplicable arrangement of the parts composing the organ of hearing in man. The visible part, usually called the ear, performs but a very small share indeed in the performance of the functions of hearing, though of great beauty when well formed, and highly ornamental to the human head; but the functions or uses, even of the external ear, have not been made out; and much less do we comprehend the uses of the deeper parts, and of the middle ear, as it is called; of the labyrinth or internal ear; and of the appendages connected with the organ generally. But, before speaking of the presumed uses of these singular structures, let us place before the reader as brief an outline as may be of the anatomy of the organ of hearing.

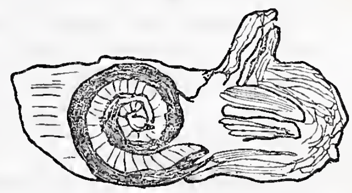
Fig. 1 (see Plate), represents the human ear, in which *a* is the cartilage, or external ear; *b*, the auditory tube; *c*, the tympanum or drum of the ear; *d*, the cavity of the tympanum, kept filled with air by means of the eustachean tube, *e*, which comes from the back of the mouth. It is owing to slight congestion of this, that in a common cold we experience a little deafness. At *f* is seen a chain of four little bones; at *g* a cavity called the vestibule; at *h* three canals called the semicircular canals; and at *i*, the cochlea.

The vestibule, the cochlea, and semicircular canals constitute the labyrinth or internal ear, which is the true organ of hearing. The subjoined figure will give the reader some idea of the osseous shell shutting in the membranous and nervous structure found within the labyrinth. *a* is an opening called a fenestra, leading into the cavity of the vestibule;

Fig. 1.

b, the semicircular canals; *c*, the cochlea. In order to see the contents of these cavities, the external osseous wall must be filed off, and the same structures will then assume the appearance represented in the annexed figure. Into

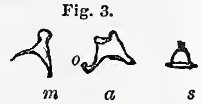
Fig. 2.



the labyrinth passes the auditory nerve, by means of which, no doubt, the vibrations of the external air are conveyed in a mysterious manner to the brain, giving us the sensation and perception of sound.

But on the interior of this deep or internal ear, there is an apparatus of structures called the *middle ear*. This is also composed of three parts—namely, the tympanum, which is a cavity; the eustachean tube, which communicates with the throat; and the mastoid cells. In the cavity of the tympanum we find a membrane which also invests the other two divisions mentioned; and besides this membrane, there are four bones of the most singular construction, and named from their very forms, the hammer, the anvil, the orb-shaped bone, and the stirrup. *m*, the hammer; *a*, the anvil; *o*, the orbicular bone; *s*, the stirrup. These bones form a sort of chain, connecting the drum of the ear, which is situated exterior to them, and the vestibule, the base of the stirrup bone being placed within the opening called the fenestra ovalis, an opening which, we have already said, leads directly into the vestibule. The drum of the ear, on the other hand, against which the hammer bone rests, is a circular membrane of a peculiar structure, which may be made more or less tense by means of muscles acting on the chain of bones.

Fig. 3.



On the outer side of the drum of the ear is the membranous and cartilaginous tube which, extending outwards, terminates in the external or figured part of the ear, visible on the side of the head. If water or any liquid be injected into the external opening of the ear, it does not penetrate further than the drum of the ear, so long as that membrane remains healthy and entire. The drum may, however, be diseased and ulcerated; and it has been punctured by the surgeon for a peculiar form of deafness, and then air or tobacco smoke may be forced from the throat and made to appear at the external ear; but not otherwise. A more minute description of the organ would not much avail the reader in understanding the mere mechanism, nor would it enable him the better to comprehend the physiology of the organ. Here, as in many other organs of the body, we should never have discovered by mere anatomy alone the uses of the structures; of this curious fact, the brain and ear form striking *examples*.

By hearing, is meant, physiologically speaking, the distinguishing, appreciating, and perceiving the undulations or vibrations excited in matter, and communicated by means of

the auditory nerves to the brain. Pulsations of the air, water, or solid bodies, are communicated to the ultimate fibrils of these nerves, and the changes produced in them, extending to the brain, are perceived by us as sounds.

The external ear and its associated apparatus, may be considered as conductors of sound. It is quite certain, however, that the loss of the external ear has in numerous cases interfered in no shape with the accurate perception of sounds. On the other hand, the external ear in many animals, as the horse, ox, dog, &c., must perform the functions of a real acoustic tube. But we shall adhere chiefly to the ear of man throughout the following observations.

It is presumed that sounds pass usually along the external passage of the ear towards the drum of the ear, against which they impinge, and cause it to vibrate. This passage of the ear is unquestionably an important part in ordinary or normal hearing. A number of fine hairs grow within the tube; the walls are formed partly of the common integuments of the body reflected inwards. Even the scarf skin itself passes quite to the bottom of the tube, and is reflected entire over the drum of the ear. Besides this, a series of small glands exist here, whose office is to secrete the peculiar substance called the wax of the ear; a deficiency of this wax affects the utility of the organ very considerably; so also perhaps, a too great abundance of wax, or its altered qualities.

In eager listening, the mouth opens instinctively, and this has been supposed to widen the tube of the ear, by altering the position of the condyle of the lower jaw bone. The dullness of hearing in very young children has been ascribed to the natural narrowness of the auditory tube in them; but other causes, no doubt, contribute to this.

In dullness or loss of hearing, the remedial means within the power of the surgeon are nearly confined to the condition of this part of the organ, the external tube, and to the drum of the ear. For this reason, the most careful examination should always be made of these parts, even in those who have been *reputed* deaf from infancy, for in many cases the deafness may have come on merely during infancy, and may not have been congenital. I remember the case of a person who was reputed to have been deaf and dumb from his very earliest years, and no doubt he was in reality so; but on examining his ears after death, the tube in one was found filled with inspissated cerumen or wax, the pressure of which, apparently on the drum, had caused a small opening to form in it; all other parts of this ear were quite sound, and of a healthy appearance; in the other ear, the external tube was filled with cerumen, the drum was lost, the lining membrane of the middle ear thickened and ulcerated, and the small bones bathed in purulent matter. Now, in this ear, the diseased state was probably beyond all remedy by art; but not so the other ear; whilst the condition of both showed, that with a due knowledge of the condition of the organ, and appropriate means, the hearing might have been restored.

The structures next to be considered, with reference to these functions, are the drum of the ear, and the chain of bones contained within the cavity of the tympanum. Now the difficulties multiply exceedingly, for it cannot, I think, be shown, especially as regards the four tympanic bones, that such structures and such arrangements have any known philosophical connection with the nature of sound. It is said that entire destruction of the drum of the ear by disease is always attended with deafness or loss of hearing; but physiologists of great eminence deny this statement. Even the presence of the chain of bones does not seem essential to the right performance of the function.

The uses of the eustachian tube, that is, the tube connecting the cavity of the middle ear with the throat, are supposed to be to establish static equilibrium between the air within the tympanum, and that of the external atmosphere. As it is liable to become obstructed, the practice of probing it has been much in use of late years; air also has been forcibly driven into it with a view to overcome obstructions.

OBSERVATIONS ON THE ADAPTATION OF PUBLIC BUILDINGS TO THE PROPAGATION OF SOUND, CONSISTENTLY WITH SPEECH.

By William Shand, Esq.

The following short observations are intended to show, by practical illustration, the difficulties that have been experienced in regard to the Economy of Speech in apartments, and also the rules and means by which this Economy may be effected.

General Remarks.—It is remarkable with what devoted assiduity men of science apply themselves to discover the cause of some peculiar phenomenon in nature, which, to many, appears of little importance, and may, by the rudest mechanic, be practically exhibited when the principles or laws by which it is produced are understood.

When it was discovered that the electric fluid acted by the external surfaces only of conducting bodies, to a superficial observer it seemed of little consequence, but much time and many experiments were necessary to determine this.

When Sir Humphrey Davy discovered what led to the formation of the safety-lamp, it appeared a trifling matter, but it cost that distinguished man of science much time and labour. The telescope, which brings so many distant worlds into view, is formed of bodies possessed of two simple properties—the opaque and pellucid—all else is artificial arrangement; and when optics was in its infancy, could it have been anticipated that this science would have been brought to such a height of perfection, and that many educated and able men would devote themselves solely to one department of it?

Much has been effected in the economy of heat, but it is applicable in such a variety of ways, and to so many purposes, that although much of utility is known, probably still more remains to be understood.

Difficulties in copying an erection consistently with Acoustic Principles.—The most subtle and abstruse phenomenon in the whole range of physical science is sound, which has hitherto been an *ignis fatuus.* In the very limited space of a common apartment, individuals are seen opening their mouths, stretching their necks, and putting the hand to the ear in order to catch that which is not, a false sound being to the ear what ocular deception is to the eye. All men fancy it to be within their reach—of this various instances are at present exhibited; and these remind us of a circumstance, related by several authorities, of some Jesuits who erected a building in imitation of one near Milan, where the sound of a pistol shot is repeated upwards of forty times; but although the copy was in appearance the same as the original, yet it was without an echo.

Desertion of Principles in copying Canon Mills, Edinburgh.—Canon Mills (a place intended for the preparation of gas), where the first General Assembly of the Free Church of Scotland met, is now considered a model for the economy of speech; and several places of worship have been erected as true acoustic copies of this edifice, which consists of, in part, an earthen floor, walls of rough solid masonry, and slates as they came from the quarry, affixed to wood as it left the saw, all being simple compact materials, with rugged exteriors, having little vibratory action or sound, *the solidity of the bodies and roughness of the surfaces* being the principles that are favourable to articulation by producing limited *undulations;* but the rough surfaces occasion harsh sound on the ear, in the ratio of their proximity to it.

In the copies from the original, instead of being partly earth, the floor is all boarded and hollow under, giving out much extraneous sound from the action of the feet and other causes. The walls, instead of being solid and rough, are lined with lath and plaster, hollow between, and smooth on the exterior, consequently having comparatively much more action and sound than the original; while the roof is lined with lath and plaster, in like manner as the walls; not anything being retained in the copies consistent with the properties of Canon Mills, except the general form, which is bad. All this deviation from the original seems strange, when it is considered that not a single atom in a sonorous body can be added or displaced, without influencing sound. It is also remarkable if an old building, intended for so foreign a purpose, and so rude, should be found more demon-

strative of the economy of speech than all the works of art that have been intended for this purpose.

Instance of the Class-room of a Man of Science, formed of similar materials, and producing similar Effects as in Canon Mills.—I shall now give another instance of rude and rugged materials producing similar effects, from similar causes, by moderation of action and sound. A celebrated physiologist, in his examination before the last Committee of the Commons, on the transmission of sound in apartments, &c., alludes to a particular class-room, as constructed on scientific principles, and well adapted to the purposes of speech. In it the floor is of earth, the walls of solid and rough masonry, the roof is of unplaned plank, covered above with a thick coat of compost, and supported in the central parts by pillars of brick, in their original porous state; all being comparatively solid, and rough on their exteriors. The only material difference that I can perceive is, that the old gas-house, Canon Mills, is a matter of chance in regard to sound; whereas the learned doctor's class-room has been constructed by a man of science; they are indeed very different in form, and yet form is the only point that architects seem to consider of importance in imitating Canon Mills. One advantage in both these places is, that *there is little glass exposed to the voice of a speaker.*

The materials used in Canon Mills, the physiologist's class-room, the meanest cottage, or even the barn, are alike.

Erroneous to suppose that Undulatory Action should be lengthened, and Reflections prolonged.—The learned doctor, in his further depositions, recommends that the reflections of speech, in the Houses of Parliament, should be taken from the ceilings, transversely to the direction in which the human voice proceeds from the mouth; *the direction being horizontal whether we sit or stand.* He also advises that the ceilings should be formed on the principles of a piano-forte sounding-board; thus increasing and prolonging sound and the reflection of each letter more decidedly than the copyists of Canon Mills.

It may now be proper to endeavour to ascertain the principles by which the reflecting bodies, in these two apartments, are less ungenial to articulation, than where such are more sonorous and refined in appearance, as this may lead to the beneficial use of materials possessing similar properties, but less offensive to the eye.

Reasons why Speech is less indistinct in Canon Mills and the Physiologist's Class-room than in more refined apartments.—Doctor Neil Arnot remarks, that when sound is reflected by a solid, the angle of incidence and reflection correspond; and he illustrates this by a boy's hand-ball thrown against a wall, when the angle of reflection is equal to that of incidence. But the analogy applies only in a limited degree, because the ball is kept together in mass, whereas, the component parts of the atmosphere are scattered and divided, and so is sound, as our sense of hearing tells us. The greatest repelling force is no doubt in one direction, but the matter that gives effect to sound passes, in a certain degree, in all directions; the particles in the atmosphere impinging on a rough surface, press in various directions, in conformity to the minute angles presented to them, and consequently occasion less vibratory and undulatory action in the reflecting body than when the surface is smooth and the pressure in one general direction. The component parts of the atmosphere, thus recoiling in various directions, strike upon and oppose each other, and from this cause also lessen sound. If the ear be near to such rough surfaces, they occasion harsh sound to be transmitted to the nerve of hearing; but at a little distance, the atmosphere again runs smooth, and produces no such effects.

I would next observe, as to the earthen floor, that the action and sound from it are much less than from hollow boarding—the earth is comparatively soft, little elastic, and rough externally —for these reasons, sound from it does not sensibly affect the ear, nor cause any reaction from the roof. These facts may be learned from the ground in general producing no confusion either in speech or music. The earth has also an action different from hard bodies of limited thickness, such as boards, lath, and plaster, by which motion and sound are lessened in these materials.

Angular Surfaces calculated to prevent extraneous Sounds from reaching the ear.—The apartments just alluded to are, I conceive, better calculated to demonstrate, by the rough surface and comparative solidity, the means by which harsh and ungenial reflections may be prevented from reaching the ear, than to exemplify the manner in which consistent reflections are to be obtained.

Sound reflected from Sonorous Solids in Apartments, in at least six directions, must necessarily confuse Speech.—It may be remarked, that an apartment for speech being a work of art, in which solids are in a limited space, and most of them sonorous, when from the human voice, or any other cause, sound is produced by rapidly agitating the atmosphere, it impinges on, and recoils from, the sonorous solids, on the walls, the floor, and the ceiling, in at least six different directions; and if the agitation be great, the effects are similar to what is produced in the ocean, when waves meet from various directions in a small compass, occasioning, by their conflict, confusion in sound, as it has already done in the atmosphere, by which it is conducted.

There are various ways of exemplifying this in apartments, and in the atmosphere, where sound is not confined.

All Curvatures, by concentration, confuse Speech.—Notwithstanding that all writers on this subject, so far as I have been able to ascertain, recommend excess of sound, and several advise its concentration, or being made to act in foci, wherever the human voice, in speech, acts within a curvature, articulation is deranged, and the greater the curve and the more sonorous the material, the greater is the perturbation.

The evil of extreme agitation, by changing the original character of sound, is exemplified in that of a bell, the sound of which is most clearly, intensely, and distantly heard, when there is an extremely light current of air moving from the bell towards the ear; but if the wind be strong, the component parts of the air are deranged, and sound is not heard so intensely, distinctly, or distantly.

Sonorous Solids conduct Sounds generally with velocity and intensity in a similar ratio, but in air it is equal in Velocity and Character throughout.—Sonorous solids are considered to conduct sound with velocity much in the ratio of the intensity with which it is produced—concrete plaster 11 or 12 times, and glass and fir wood with 15 or 16 times its velocity in common air. In the atmosphere it passes with equal velocity in all directions, if no more dense medium should intervene between the source of sound and the ear, and it is *conducted without change of character.* In solids, its character and direction are changed, and the degree of sound depends on the density of atoms, and their distance from each other. When sound reaches a solid, its direction and character are changed, from various causes, according to the nature and form of the solid. It is produced by cohesion, repulsion, and friction in the atoms, and the degree of sound is, therefore, in a great measure, dependent on the density of the atoms and their distance from each other; thus, silver and gold are less sonorous than copper, bell-metal, or glass; and lead, which is peculiarly soft, is less sonorous than any of these bodies.

Sound acts similarly in the Musical String and in Wood of long fibre.—There are other properties and arrangements in certain materials, which appear to operate, by their cohesive and repulsive principles, most powerfully in one direction; for instance, in wood of long fibre *it acts predominantly in the direction of the fibre, similarly to that in the musical string.*

Not only do these circumstances lead to a knowledge of the degree and character of sound emitted from various bodies, and tell us that every atom acts its part in producing it; but an understanding of all these points is necessary for the control and guidance of this singular phenomenon.

Sound being produced in Solids, acts throughout all their atoms.—On striking a solid, so as to produce sound, every atom in it is set in motion, and if another sonorous solid be in contact with it, similar effects are produced in the second as in the first solid, until by friction the atoms are brought to rest, when sound also ceases.

Predominating influence in the Solids, but air also necessary to produce Sound.—For the reasons given, in the solids* usual in apartments, sound operates with more intensity and rapidity than in the atmosphere alone (although the solid must be in contact with air), but the predominating influence is in the solids.

It is evident, from these and other understood facts, that it is

* Professor Liebig says, that every atom in the earth has its own atmosphere, and every atom in the finest metal must have its own atmosphere to produce sound. He also remarks, that cork and india-rubber have done more than anything else, in the course of the last fifty years, for the improvement of chemistry; and such bodies as these, buff leather, and woollen cloth, may do much for the economy of sound.

in the solids in and surrounding an apartment, that sound must be regulated.

Cross Sounds not admissible, &c. Necessity of regulating Undulation in the Solids.—I have already explained that neither cross sounds nor excessive sound is admissible, and that reflections which reach the ear must fall on the pinna horizontally—that the undulatory motion in the reflecting bodies must be regulated; and I shall further demonstrate the means by which this is to be effected, and those by which cross sounds are to be withheld from the ear, without exposing soft non-sonorous materials, so as to arrest the tremulous atmosphere and sound generally in an apartment. I have certainly explained enough to convince the most sceptical that it is preposterous to imagine that all that is requisite to be attended to is the mere form of a room, or that materials may be thrown together indiscriminately, conducting and reflecting in various directions and in any degree. As sound passes with equal velocity in all directions in the atmosphere, the first solid that the voice of a speaker must operate on, is that nearest to him, and, being conducted with so much greater rapidity by the solids than in air, it must pass by the solids, and by these be given out to the atmosphere.

Effects of the predominating velocity and intensity of Action and Sound in the Solids.—For instance, supposing an apartment 85 feet in length, and half this width, and that the speaker is placed in one end against the wall, the sound of his voice passes by the atoms of the solids in the walls to the other end of the room when it is only a few feet from his mouth in air, and *as undulation succeeds undulation* with so much greater rapidity and intensity of effect in the solids than in air, the predominating influence must be in the solids.

Prevention of Echo insufficient to economise Speech.—Many suppose that preventing echo and a repetition of reflection is sufficient; but this is only a palliation of the evils experienced, because a single reflection, although it may be prolonged too much, is less prejudicial than a repetition of reflection.

For the reasons given, irregular reflections of the voice and extraneous sounds are so general that, although the ear may not be sensible of these individually, they interfere more than we are aware with those which convey distinct and intelligible sounds to the nerve and sense of hearing.

Further general observations.—In different phenomena, causes and effects vary; but, reasoning by analogy between hearing and sight, I would remark, in regard to the faculty of vision, that, if the eye be directed to two objects at the same time, perception is less in both than if concentrated on one object. Are not cross lights or rays approaching the eye in transverse directions prejudicial? and shall sound, without measure or adjustment, be communicated to the ear with impunity?

The circumstance alone of speaking without oppression and with ease in all places where the soft material has been used, is, of itself, very important, as many say they would rather speak a whole day in one place, than two hours in another place. The following hypothesis I believe to be applicable in this case:—

If several musical instruments are in tune, and operating in concert, the ear receives their sounds from a distance as if one instrument; but if any instrument gives out discordant sounds, this tends to overcome the more musical sounds and derange the whole. Precisely such are the effects produced by reflected sounds from the solids in an apartment; in the one case, they give consistent strength and effect to each other, but in the other case they produce discord. If in a room certain of the walls are of solid masonry, and others of lath and plaster, and the ceiling is on the principles of a piano-forte sounding board, all having different degrees of action and sound operating in opposition to each other, is it possible that there can be any accordance in the sonorous effects? Causes and effects are in this case similar to that of a complicated piece of mechanism, in which the parts do not fit and move together, but oppose each other; for sound is entirely the offspring of mechanical action in the matter which produces or conducts it.

Mode of Regulating Reflected Sounds intended to reach the ear.—The chief objects in the arrangements alluded to are to obtain reflected sounds of the voice in speech from vertical bodies, so that they may be delivered horizontally on the pinna of the ear, being obviously the direction in which this expanded vibrating lever is best calculated to receive these.

All such reflected sounds must be regulated by the undulatory action in the reflecting solid, each undulation being made to conform in time and duration of sound, as nearly as may be, to the motion of the mechanism of the mouth in the formation of every distinct letter; and these reflections must not be so excessive as to produce any sensible reflection or echo from an opposite solid. To effect these objects, soft non-sonorous material is placed behind, and on the edges of the reflecting sonorous bodies, according to circumstances, so as to moderate the reflections *and shorten the undulations.*

Nature points out that the reflected sounds of the voice should fall on the ear in a horizontal direction, because the voice proceeds from the mouth in this direction whether we sit or stand, and because all cross action in the atmosphere differing from this is found prejudicial.

Means for Preventing Irregular Sounds from reaching the ear, &c.—In order to prevent cross action and derangement in the sonorous atmosphere and in speech, and to keep extraneous sounds from the ear, a greater proportion of soft non-sonorous material must be placed on the unexposed parts of the ceiling and on all sonorous bodies that do not reflect horizontally; but this soft non-elastic material must not be exposed to the atmosphere or the direct action of the voice, except on the floor, because in this case it damps the sound of the voice too much throughout an apartment. By the expansion of air in a room, it ascends, and the sound-producing vibrations naturally ascend with it, acting predominantly on the roof, and not much on the floor, which is, moreover, occupied and covered by the audience to a greater or less extent. Soft material—as matting, or, in places of miscellaneous resort, saw-dust—may, therefore, be placed on the floor, without appreciable injury to the voice of the speaker. Some asphaltic compositions—with a preponderance of bitumen, to destroy their sonorous qualities—may be employed with advantage. Extraneous sounds may also be operated on by means of rough or angular surfaces, so as to cause the particles in the atmosphere to act in opposition to each other, in order to break and divide sound, and thus prevent it from reaching the ear. Nature exhibits to us the surface of the ground always in a rough state, so as to prevent any moderate degree of sound, such as emanates from the human voice, from occasioning confusion, because the reflections do not reach the ear.

Lath and plaster are not the most desirable materials for the lining of an apartment; and often in churches, the windows are injudiciously and prejudicially placed, without sufficient means being adopted to keep back from the ear the intense and irregular sound given out by the glass.

THE PROPERTIES OF THE CATENARY.

If a flexible cord, rope, or chain of uniform substance and texture be hung loosely by the extremities between any two points of suspension, it being a matter of indifference whether the points be in a horizontal line, the figure which it naturally assumes and in which it remains at rest, is a peculiar curve denominated the *catenary*, a name derived from the Latin root *catena*, signifying a chain or cord.

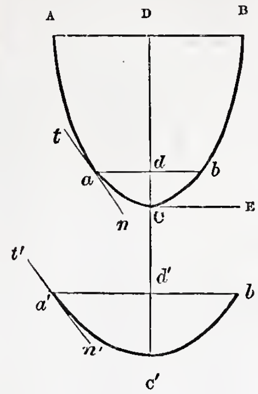
This curve, mechanically considered, derives its importance from its intimate connection with the construction of bridges, whether they be built on the ordinary construction of stone or cast-iron, or on the method of suspension by wrought-iron chains.

In reference to the formation of the curve, we remarked that in order to secure its being correctly described, the suspended material ought to be of uniform substance and texture, the object being to have it uniformly pliable and heavy throughout its length. In fact, any want of pliability or readiness to yield to any force applied laterally, essentially alters the nature of the curve; on this account, a chain is likely to afford a more correct curve than a cord. The property of being uniformly heavy throughout is the only positive quality of the material essential to the description of the curve, and it may be stated more particularly by observing that the original force by which the curve is generated is the force of gravity acting equally upon every part of the suspended line; it follows, therefore, that the acting force may be resolved into an infinite series of smaller equal forces acting vertically at indefinitely small distances apart upon the whole length of line suspended.

Let A, B, the extremities of the horizontal line A B, be the

points of suspension of a chain A C B, which hangs at rest in a vertical position. The position A *a* C *b* B assumed by the chain is termed the catenary curve. If the distance A B be bisected in D, and the perpendicular D C drawn to the curve at C, it is clear that, as the circumstances under which the two portions of the chain are placed are exactly the same, the line D C will divide the curve into two equal and symmetrical portions A *a* C, B *b* C, which balance each other precisely at C, the lowest point in the curve. If from the vertex C a horizontal line C E be drawn, it will be a tangent to the curve at that point, and will represent the direction of the tension upon the chain at C, created by the oblique positions of the parts of the chain A C, C B; if, therefore, the part B C were removed, the remaining part A C would fall into a perpendicular line from the point A; but suppose it to be prevented by a force acting horizontally at C and equal to the weight of a portion of the chain of which the length is represented by C E, then the equilibrium of the portion A *a* C will be undisturbed, and the tension at C will be represented by the line C E; this line is also regarded as the *parameter* of the curve.

Fig. 1.



When the chain hangs at rest, all its parts being in equilibrium, its condition is similar to that of a rigid body; and were any two points *a* and *b* of the curve to be fixed to pins or other points of resistance, the parts A *a*, B *b* might be removed, and the portion *a* C *b* would remain unaltered. In either case the tension at the points *a*, *b*, must be in the direction of the tangents at the points, and also sufficient to maintain the curve *a* C *b* at rest.

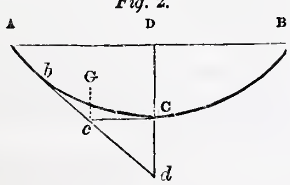
Catenaries that make equal angles at the points of suspension with their ordinates or horizontal dimensions are similar figures, the points of suspension being supposed to be in a horizontal line, and the distance between the points of suspension bears in all of them the same relation to the depth or axis of the curve. Thus, in fig. 1, let *a* C *b* and *a'* C' *b'* be two such curves of which *a'* C' *b'* is the flattest. Draw the tangents *t n*, *t' n'*, to these curves at the points *a*, *a'*, making equal angles with the ordinates *a d*, *a' d'* respectively, then the curve *a'* C' *b'* may be viewed as the curve *a* C *b* on a larger scale, and

$$a\,b : a'\,b' :: a\,d : a'\,d' :: d\,C : d'\,C'.$$

It is obvious too that from one of two dissimilar curves A C B, *a'* C' *b'*, a portion may be cut off the curve of greater angular extent, A C B, similar to the other curve *a'* C' *b'*. Thus, having drawn the tangent *t' n'* to the curve *a'* C' *b'*, at *a'* the point of suspension, a tangent *t a n* may be drawn to the curve A C B, parallel to *t' a' n'*, and touching at *a*; through *a* draw the horizontal line *a b*; then *a* C *b* is similar to *a'* C' *b'*.

To deduce the geometrical properties of the catenary, let the chain, fig. 2, be suspended from the points A, B, the lowest point of which is at C. If at any point *b*, a tangent *b c* be drawn to the curve meeting the horizontal line C *c* at *c*; then the portion *b* C of the curve must be held at rest by two forces acting tangentially at the points *b*, C, that is, in the directions *c b*, *c* C. This being the case, the weight of the portion *b* C, which is the force resisted by these two forces, must act at their point of intersection *c*; or in other words, the centre of gravity G, of the curve *b* C, must be in the perpendicular line *c* G, passing through *c*, in order to complete the equilibrium. If then *b c* be produced to meet the vertical D C produced at the point *d*, the sides of the triangle of equilibrium C *c d* will represent the relative directions and magnitudes of the three forces; of these, the weight of the curve or portion of the chain *b* C, is expressed by C *d*, the horizontal strain at C by C *c*, and the oblique strain at *b* by *c d*. And as C *c* is parallel to A B, it represents the horizon, and the angle C *c d* is the angle which the force at *b* makes with the horizontal line.

Fig. 2.



From the above construction, we find

$$\left.\begin{array}{c} C\,c : C\,d \\ \text{or tension at C : weight of C}\,b \end{array}\right\} \begin{cases} :: \sin C\,d\,c : \sin C\,c\,d \\ :: \cos C\,c\,d : \sin C\,c\,d \\ :: \text{radius} \quad : \tan C\,c\,d \end{cases}$$

Hence, the horizontal strain at C being constant, the *weight* and therefore also the *length* of any portion C *b* of the curve is proportional to the tangent of the inclination of the curve to the horizon at the point *b*, the extremity of that portion.

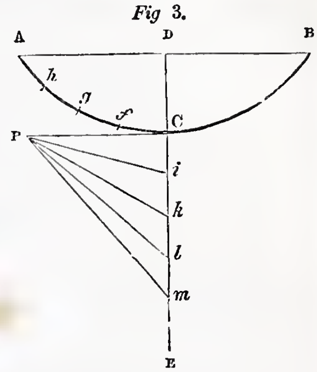
Again,

$$\left.\begin{array}{c} C\,c : c\,d \\ \text{or tension at C : tension at}\,b \end{array}\right\} \begin{cases} :: \sin C\,d\,c : \sin C\,c\,d \\ :: \cos C\,c\,d : \text{radius} \quad d \\ :: \text{radius} \quad : \sec C\,c \end{cases}$$

Therefore again, the strain at C being constant, the strain exerted tangentially at any point *b*, is proportional to the secant of the inclination at that point.

These two propositions may be graphically expressed by the following simple construction. Let A C B, (fig. 3), be a chain suspended by A and B; through C, the lowest point in the curve, draw the vertical line D E, and the horizontal line C P, expressing the direction and amount of the strain at that point in terms of the length of chain of which the weight is equal to the tension. In the curve C A take any number of points *f*, *g*, *h*, and through P draw P *i* parallel to the tangent to the curve at *f*; draw also the lines P *k*, P *l*, P *m*, parallel to the tangents at *g*, *h*, and A. Then P C being the tension at C, P *i* expresses the tension at *f*, and C *i* the third side of the triangle is the weight of the portion of chain C *f*, which combined with P C, produces P *i*. In like manner, P *k* is the tension at *g*, P *l* the tension at *h*, and P *m* the tension at the point of suspension A; also the lengths *i k*, *k l*, and *l m*, respectively represent the weights of the portion of the chain, *f g*, *g h*, *h* A, and C *m*, of course expresses the weight of the half length A C.

Fig 3.

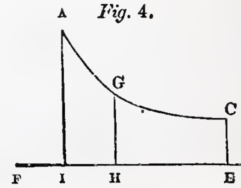


Now C P being the radius, the lines C *i*, C *k*, C *l*, and C *m*, are clearly tangents to the inclinations at the respective points *f*, *g* *h*, and A, and also express the weights of the segments C *f*, C *g* C *h*, and C A. And relatively also the lines P *i*, P *k*, P *l*, and P *m*, the tensions at the corresponding points of the curve, are the secants of the inclinations; which are the propositions already stated.

This simple method of finding the tensions and weights of segments of the chain becomes very convenient when the lines employed about the construction are all expressed in terms of a common unit of measure; the length of chain namely, of which the weight is taken as a unit of weight. By this arrangement, the lengths and weights of segments of the chain, and the tensile forces to which they are subject, being all expressed in lines drawn to the same scale, are directly comparable. Consequently, having the half length of chain A C given, and the tension at C, the triangles C P *m*, C P *l*, &c., may be constructed; and, consequently, the tensions at the point A, or any intermediate point may be found without reference to the inclination of the curve at these points.

Another very simple process for finding the tensions upon the different points of the curve is the following:—

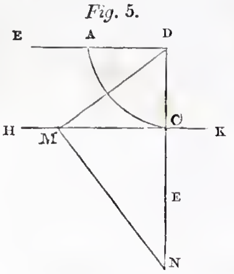
Fig. 4.



From the lowest point C in the curve, fig. 4, drop the perpendicular C E, equal to the parameter of the curve. Through E draw the horizontal line E F. Then the tension at any other point G will be represented by the perpendicular G H to the line E F; and the perpendicular, A I expresses the tension at the point of suspension.

Seeing, therefore, that the horizontal strain at C, otherwise named the parameter of the curve, holds an important position in practical applications, we have now to point out the method of finding that element. And first, to find it geometrically, the following method, given by Mosely*, is easy of application Draw the horizontal lines E D, and H C K, and the vertical D C N; take a straight line D M, equal in length to the curve C A, and describe a circle from the centre D, meeting the line H K in M. From M draw a straight line M N, perpendicular to D M, and bisect N C in E; C E is the parameter of the curve.

Fig. 5.



The following simple formulæ, given by Leslie,† also apply in all those cases where the depression is small compared with the length of the chain. Let the distance A B, fig. 1, $= d$, the height C D $= h$, the length A C B $= l$, the parameter $= p$, and the strain at A or B $= a$. Then,

$$p = \frac{d^2}{8h} - \frac{1}{6}h, \; a = \frac{d^2}{8h} + \frac{1}{6}h;$$

$$\text{or } p = \frac{l^2}{8h} - \frac{1}{2}h, \; a = \frac{l^2}{8h} + \frac{1}{2}h;$$

$$l = d + \frac{8h^2}{3d}.$$

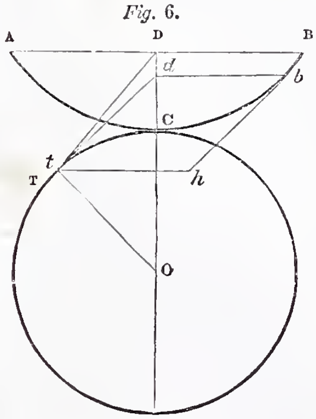
The distance of the centre of gravity of the whole curve, l, from the vertex is $\frac{1}{2}\left(h \times \frac{pd}{l} - p\right)$.

From these formulæ it will appear, too, that the strains p and a are in nearly the inverse ratio of the depressions.

The following is the method given by Dr. Gregory in his "Mechanics for Practical Men," for finding intermediate lengths and tensions upon the chain :—

Let C O, in the axis produced downwards, be taken equal to the parameter or measure of the horizontal strain at C, and upon O as a centre, with radius C O, describe a circle. Take any portion C b, of the catenary from the lowest point, draw the ordinate b d, to the axis, and from d draw a tangent d t, to the circle. This tangent will be parallel to the tangent b h drawn to the curve at b and will also be equal in length to the corresponding portion b C of the curve. In the same way, if D T be a tangent to the circle drawn from D, it will be parallel to the tangent at B, and will be equal to the half length of curve B b C. It appears, too, that the distances O d, O D being secants to the tangents d t, D T they express the tensions at the points b B; evidently exceeding the parameter O C, or tension at C, by the abscisses C d, C D. Thus this method may be considered as combining the methods represented by figs. 4 and 5.

Fig. 6.



The following table, abridged by Dr. Gregory from a very extensive one given by Ware in his "Tracts on Vaults and Bridges," will greatly assist the engineer in his calculations. It will be observed that the parameter, as a datum line, is supposed to be equal to 1. The whole theory of catenary curves may be verified experimentally, by means of spring steel yards applied to a chain of given length and weight, suspended in various positions.

* Mechanics applied to the Arts.

† Elements of Natural Philosophy.

Table of Relations of Catenarian Curves, the Parameter being denoted by 1.

Angle of suspension.	D C	D B	C B	Tension at A or B	D B ÷ D C
1° 0′	·00015	·01745	·01745	1·0001	114·586
2 0	·00061	·03491	·03492	1·0006	57·279
3 0	·00137	·05238	·05241	1·0014	38·171
4 0	·00244	·06987	·06993	1·0024	28·613
5 0	·00382	·08738	·08749	1·0038	22·874
6 0	·00551	·10491	·10510	1·0055	19·046
7 0	·00751	·12248	·12278	1·0075	16·309
8 0	·00983	·14008	·14054	1·0098	14·254
9 0	·01247	·15773	·15838	1 0125	12·654
10 0	·01543	·17542	·17633	1·0154	11·372
11 0	·01872	·19318	·19438	1·0187	10·820
12 0	·02234	·21099	·21256	1·0223	9·444
13 0	·02630	·22887	·23087	1·0263	8·701
14 0	·03061	·24681	·24933	1·0306	8·062
15 0	·03528	·26484	·26795	1·0353	7·508
16 0	·04030	·28296	·28675	1·0403	7·021
17 0	·04569	·30116	·30573	1·0457	6·591
18 0	·05146	·31946	·32492	1·0515	6·208
19 0	·05762	·33786	·34433	1·0576	5·863
20 0	·06418	·35637	·36397	1·0642	5·553
21 0	·07114	·37502	·38386	1·0711	5·271
22 9	·07853	·39376	·40403	1·0786	5·014
23 0	·08636	·41267	·42447	1·0864	4·778
24 0	·09484	·43169	·44523	1·0946	4·562
25 0	·10338	·45087	·46631	1·1034	4·361
26 0	·11260	·47021	·48773	1·1126	4·176
28 0	·13257	·50940	·53171	1·1326	3·843
30 0	·15470	·54930	·57735	1·1547	3·551
32 4	·18004	·5912	·62649	1·1800	3·284
34 16	·21003	·6371	·68130	1·2100	3·034
36 52	·24995	·6932	·74991	1·2499	2·773
39 11	·29011	·7443	·81510	1·2901	2·567
41 44	·34004	·8029	·89201	1·3400	2·362
44 0	·39016	·8566	·96569	1·3902	2·196
46 1	·43999	·9066	1·0361	1·4400	2·060
48 11	·49981	·9623	1·1178	1·4998	1·925
50 8	·56005	1·0142	1·1974	1·5800	1·811
52 9	·62973	1·0706	1·2869	1·6297	1·699
54 13	·71021	1·1304	1·3874	1·7102	1·592
56 28	·81021	1·1995	1·5089	1·8102	1·481
58 3	·88972	1·2510	1·6034	1·8897	1·416
60 0	1·0000	1·3169	1·7321	2·0000	1·317
64 6	1·2894	1·4702	2·0594	2·2894	1·140
67 28	1·6095	1·6135	2·4102	2·6095	1·002
67 32	1·6168	1·6164	2·4182	2·6168	0·9998

The following examples may be given as specimens of its use and mode of application.

Ex. 1. Suppose that the span of a proposed suspension bridge is 560 feet, and the depression in the middle $25\frac{7}{8}$ feet; what will be the length of the chain, the angle of suspension at the extremities, the ratio of the horizontal pressure at the lowest point, and the oblique pressures at the points of suspension, with the entire weight of the chain?

Here D B ÷ D C $= 280 \div 25·875 = 10·82$, a number which is to be found in the table.

Opposite to that number, we find 11° for the angle of suspension, D B $=$ ·19318, C B $=$ .19438, tension at A or B $=$ 1·0187, the constant tension at the vertex being 1.

Consequently, ·19318 : ·19438 : : 560 : 563·48, length of the chain.

Also, Horizontal pressure at C is as 1·0000
Oblique pressure at A or B . is as 1·0187
Entire weight of chain. . . is as ·39876

Ex. 2. Suppose that while the span remains 560, the depression is increased to 51.

Here D B ÷ D C $= 280 \div 51 = 5·49$. This number is not to be found exactly in the table. The nearest is 5·553 in the last column, agreeing with 20°, the angle of suspension.

Now, $5·55 - 5·49 = ·06$, and $5·55 - 5·27 = 28$, the former difference being nearly one-fifth of the latter. Hence, adding

to each number, in the line agreeing with 20°, one-fifth of the difference between that and the corresponding number in the next line, we shall have

Angle of suspension $= 20° 12'$, D C $=$ ·06556, D B $=$ ·36010, C D $=$ ·36797, tension at A $=$ 1·10656.

Hence ·36010 : ·36797 : : ·560 : 572·24, length of chain.

Also, horizontal pressure at C . .	is as 1·0000
Oblique pressure at A or B .	is as 1·10656
Entire weight of chain . .	is as ·73594

Comparing this with the former case, it will be seen that the tensions at C and A, in reference to the weight of the chain, are diminished nearly in the inverse ratio of the two values of D C; thus confirming the remark which we made on this point.

In practical cases with regard to bridges of suspension, it will be easy, when the weight of the material and its cohesive strength are known, to find the relative strength of any proposed structure.

If the angles of suspension, made between the tangent to the curve at A or B and the horizon, be 45°; then $d : l : : 1 : 1·1346$.

When $l = 2\ d$, then $h = ·7966\ d$, and s $= 77° 3$.

When the angle s of suspension is 56° 28′, then $p.\ h.\ \frac{1}{2}\ d$, and $\frac{1}{2}\ l$ are as 1, 0·81, 1·1995, and 1·5089 respectively. In this case, the tension at the point of suspension is a *minimum* with respect to d.

JOHNSTON'S PATENT SHEET WATER-SPACE BOILERS.

This boiler consists of two parts, analogous to the fire-box and cylinder of a locomotive boiler. Fig. 1 is a lateral elevation of the fire-box, and fig. 2 is an end elevation of the same; fig. 3 is a vertical transverse section of the body of the boiler. The fire-box consists of the box *a b c d*, fig. 1, and *b c h i*, fig. 2, within which the fire grate *g* is set, extending from front to back; three coniform tubes *e, e, f*, are fixed upon the top and bottom of the box, between which and the tubes communication exists by a narrow opening throughout their length, as may be observed in fig. 2. The fire-box consists of an outer and inner shell, which are bolted together by rivets at regular intervals, similarly to locomotive furnaces, but differing from these by being bolted both at the sides and at the roof, dispensing with the iron ribs employed to strengthen the flat roofs of the fire-boxes of locomotives. Both ends of the water-space between the shells of the fire-box are made water-tight by a piece of iron of the same breadth as the space rivetted between the plates. The coniform tubes, *e, e, f*, are provided with flanges at the larger end, by which they are bolted to one end of the body of the boiler fig. 3.

Fig. 1.

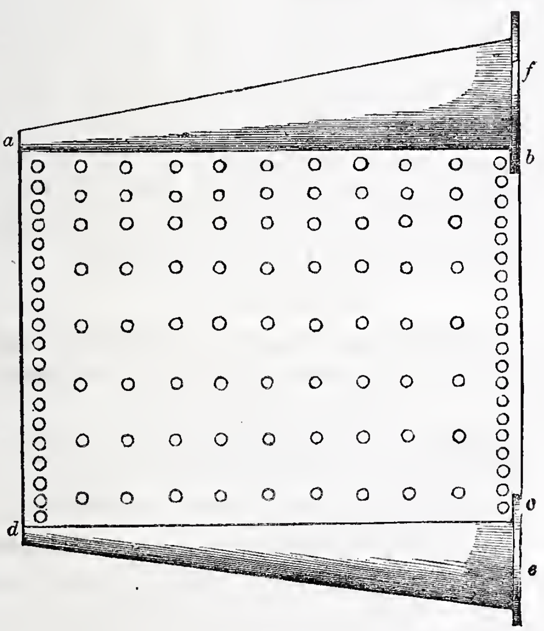
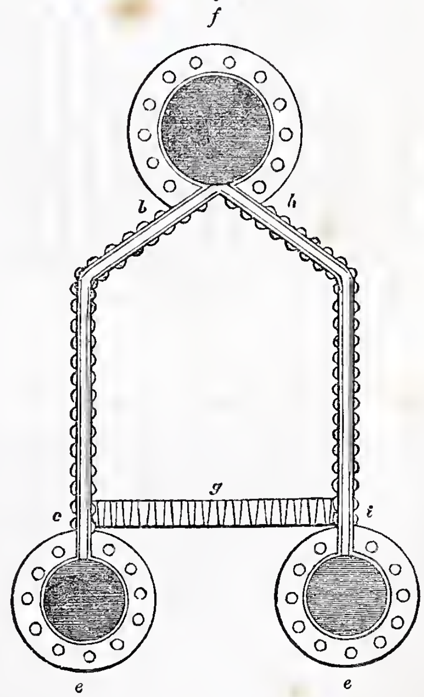


Fig. 2.



The body of the boiler, fig. 3, is made to any required length. It is furnished with a number of flues *a*, &c., which run longitudinally through the boiler, and form the passage for the inflammable gases which rise from the furnace. They enclose between them thin flat water-spaces, from which the boiler derives its name. The outer flues, *a′, a′*, are filled with any non-conductor of heat, as fire-clay, with the view of preventing the fire from acting upon the two large water-spaces *b, b*.* *c, c*, is the water-line.

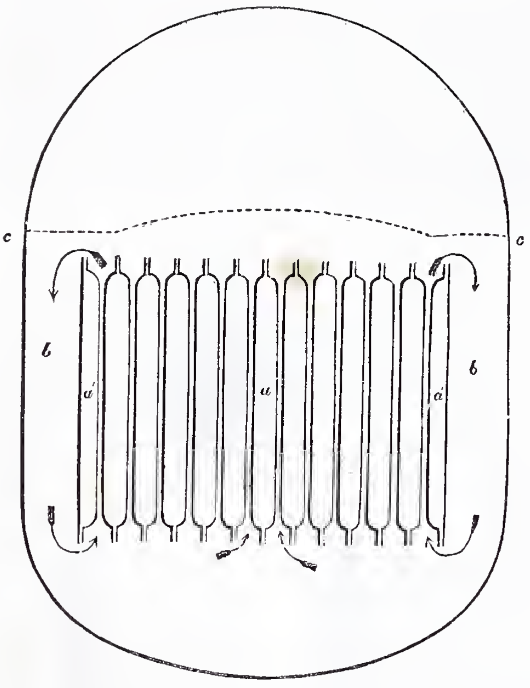
To describe the action of the boiler, it must be premised that water of a higher temperature is lighter than that of a lower, as it is more expanded, and therefore possesses less density: thus, the hotter water continually tends to rise to the surface. Steam

* There appears to be no necessity for using any other substance than the water of the boiler itself for the purpose in view; and this might be very easily managed by enclosing a sheet water-space alongside each exterior flue. The water in this space would thus be kept in continual circulation like that in the others; and, besides being a more elegant arrangement, would operate as a *non-conductor* much more effectually than the fire-clay, by continually carrying off the heat under the form of steam.—Ed.

is fully 1500 times lighter than water, and will therefore, in all circumstances, rise to the uppermost parts of the boiler. Now, in fig. 2, it will be obvious, that as the heat of the fuel is communicated to the water enclosing the fire-box, the water will rise to the surface, and make way for cooler water from below to be heated in its turn. When at last steam is formed, it immediately rises into the upper tube *f*, where it is collected, and passes into the body of the boiler. The water thus converted into steam is replaced by the water of the boiler, which flows into the reservoirs *e, e*, whence it rises into the water-spaces around the fire-box. The reason of the conical form of the tubes or reservoirs *e, e, f*, is obvious on considering that, as the water flowing into the tubes *e, e*, is taken up into the fire-box as it advances, there is continually less space required for its easy transmission. In the same way, in the steam tube *f*, the steam rises equally into all parts of it, and there is therefore the greatest amount collected near the mouth, or junction with the boiler, whence it is discharged into the body of the boiler.

In the body of the boiler, fig. 3, a distinct action is going on.

Fig. 3.



When steam is formed in the water spaces, between the flues, the water in the spaces, *b, b*, by its preponderance, immediately rushes down and displaces the steam, which rises into the upper part. This operation gives rise to a constant circulating current of water between the flues, which keeps them free from injurious deposites of solid matter, prevents the accumulation of steam between the flues, and also insures a uniform and steady action of the boiler. The arrows in the figure are sufficient to indicate the general course of the current.

A seven-horse-power boiler and furnace, of the above construction, was working in sea water for six weeks. During all that time, the water in the boiler was maintained at a greater density than the water is ever regularly worked at in the boilers of sea-going steamers, and yet there was no deposite whatever either upon the flues or furnaces of the boiler. The width of the water spaces between the fire-boxes of that boiler were only a quarter of an inch; this was also the width of the water spaces between the flues.

PROPOSED SLIDE-VALVE FOR LOCOMOTIVE ENGINES.

Fig. 1 is a vertical section of a portion of the steam-chest, exhibiting the arrangement of the new valve; fig. 2 is a plan of the same; *a* is the valve, planed parallel on the upper and under sides. It slides between the valve-face *b b* on the cylinder, and the upper side *c c* of the steam-chest, between which it works

Fig. 1.

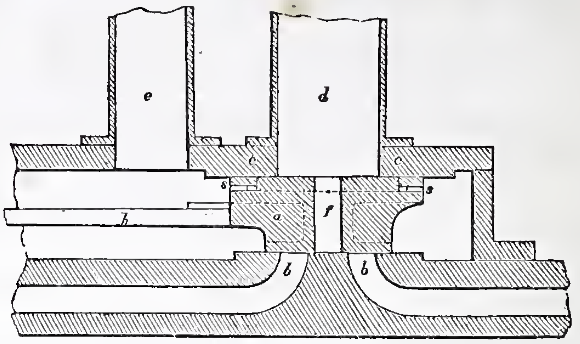
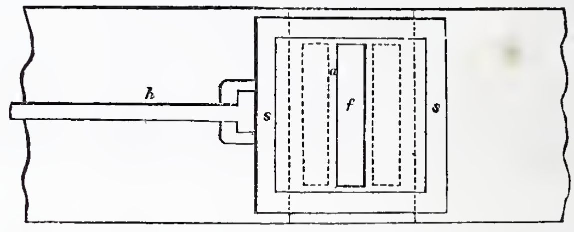


Fig. 2.



steam tight by the assistance of the plate *s s*, which, as seen in the plan, is a four-sided piece of metal, fitting upon the top of the valve, and held against the surface above it by means of springs; *d*, is the exhaust-pipe; *e*, the steam-pipe; *f*, an exhaust-passage through the valve; *h*, the valve-rod.

The steam, supplied from the pipe *e*, and surrounding the valve, is admitted to the steam-ways *b b*, alternately, by the motion of the valve, from which it again escapes into the exhaust-pipe through the passage *f* in the valve. The advantages of this valve are—a considerable diminution of the power usually necessary to work the steam-valve, and therefore less wear of the working surface; also the exhaust-passage is straight, and admits of a readier exit for the escape-steam.

ENGINES OF THE WEST INDIA MAIL-PACKETS.

CONSTRUCTED BY MESSRS. CAIRD AND CO., GREENOCK.

(Illustrated by Plates I. and II.)

Description.—Plate I. represents one of the engines in two end elevations, at the cylinder end and at the crank end.

Plate II. A, is a longitudinal section of the engine.

A, A, the kelsons, on which the engines are founded.

B, the sole-plate of the engine.

C, the columns and entablature erected on the sole-plate, on which the crank-shaft bearings are erected.

D, the diagonal stay, connected at three points, to the framing, C, the paddle-beams, O, and the cylinder. *a, a*, tie rods between the diagonal stays. *b, b*, the wings of the diagonal-stays, by which these are bolted to the paddle-beams. *c, c*, the plummer-blocks, or pedestals of the crank shaft. *d, d*, the square joints by which the diagonal stays are bolted to the cylinder-flange.

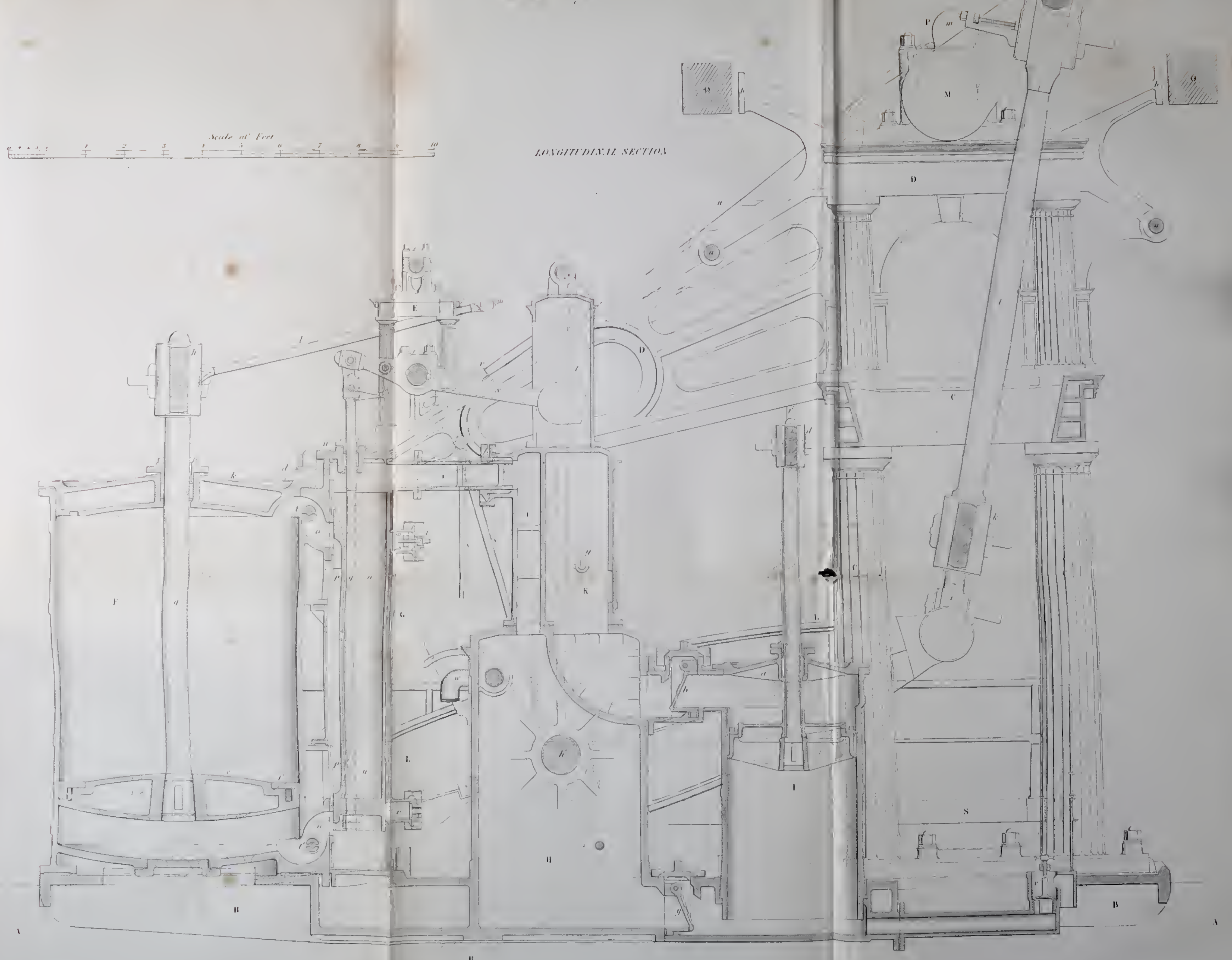
E, the parallel motion and valve-shaft frame, cast on the stay, D.

F, the steam cylinder; *e*, the piston; *f*, the junk ring; *g*, the piston-rod; *h*, the cross-head; *i*, the side rods; *k*, the cylinder-cover; *l*, the parallel-motion.

G, the nozzles; *m*, the steam-pipe; *n*, the valve; *o, o*, the steam-ports; *p, p*, the brass facings on the cylinder; *q*, the valve-spindle; *r, r*, packing boxes behind the valves for holding it to the face of the cylinder; *s*, a continuation of the

ENGINES OF THE WEST INDIA MAIL PACKETS.

Constructed by Messrs. Caird & Coy. Greenock.



valve-lever, with a counter-weight; *t*, a chest on the top of the hot well, for concealing the counter-weight; *u*, cover of the nozzle-casing.

H, the condenser; *v*, passage to the condenser, for the exhaust steam; *w*, the injection-cock; *x*, the injection-cock from the bilge.

I, the air-pump; *y*, the foot-valve; *z*, the bucket; *a'*, the cover of the air-pump; *b'*, the discharge-valve; *c'*, the air-pump rod; *d'*, the cross-head; *e'*, the side-rods; *f'*, guide-rods.

K, the hot well; *g'*, the barometer gage-cock.

L, the sway-beam; *h'*, the main centre, *i'*, *k'*, the links and cross-tail; *l'*, the connecting-rod.

M, the crank.

N, the paddle-shaft.

O, the paddle-beams.

P, the eccentric; *m'*, the counter-weight; *n'*, the eccentric rod and strap; *o'*, the starting-handle; *p'*, the starting-handle shaft; *q'*, lever on the shaft *p'*; *r'*, short gab-rod, jointed to the end of the lever *q'*, for working the valve-motion at starting; *s'*, *s'*, levers for setting the gabs in or out of gear; *t'*, *t'*, priming valves; *u'*, blow-through valves; *v'*, shifting-valve.

Q, the expansion-camb; *w'*, the screw for shifting the camb lever; *x'*, connecting-link; *y'*, the fulcrum of the levers for working the expansion-valve; *z'*, the valve-spindle.

R, the bilge-pump.

S, the platform.

The engines are collectively of 460 H. P. nominally. The following are some of their principal dimensions:—

Diameter of cylinder,	74¼ inches.
Length of stroke,	90 "
Number of strokes per minute,	15 "
Diameter of paddle-wheel,	30 feet.
Diameter of air-pump,	39 inches.
Length of stroke,	52 "
Diameter of piston-rod,	7¾ "
Do. air-pump rod,	4½ "
Length of beam,	20 feet.
Depth of do. at the middle,	4 "
Length of connecting-rod,	16 ft. 3 in.
Diameter of do. at the neck,	" " 7½ "
Do. of main centre of beam,	" " 11 "
Do. end centre of do.	" " 5 "
Do. crank-pin,	" " 10 "

On account of a slight difference of the scales to which the drawings were made, we have attached to each plate a scale for itself.

LECTURES ON ARCHITECTURE.

BY PROFESSOR COCKERELL.

LECTURE II.

SACRED ARCHITECTURE, JEWISH AND CHRISTIAN—CIVIL ARCHITECTURE AMONGST THE ANCIENTS.

In approaching Sacred Architecture, and in discussing the technical considerations of the forms and structures of temples, we cannot but bow with respect and veneration to those motives and affections, the noblest of the human heart, which have ever urged these sacrifices to the mercy and the majesty of the Creator,—and we recognise in the Grecian or the Druid, the Hindoo or the Christian temple, the universal sentiment so finely expressed in Psalm cxxxi:—

" Lord, remember David and all his trouble!

" How he sware unto the Lord, and vowed a vow unto the mighty God of Jacob.

" I will not come within the tabernacle of mine house, nor climb up into my bed,

" I will not suffer mine eyes to sleep, nor mine eyelid to slumber, neither the temples of my head to take any rest,

" Until I find out a place for the temple of the Lord, an habitation for the mighty God of Jacob."

In excavating the foundations of the Temple at Ægina, the remains of burnt wood and bones of sacrifices were discovered, mixed, no doubt, with libations, and tears, and aspirations, as warm as those of David;—at Selinus we find the steps in front of one of the temples worn down almost to an inclined plane, by the feet of the devout. So again of the accomplishment of these vows amongst men of all ages and nations, we shall find the most solemn and full expression in the 8th chapter of the First Book of Kings, the dedication of the Temple by Solomon.

The resemblance of the plan of the Tabernacle in the Wilderness, and with its surrounding court (the first in our series, 1491 B. C.), and still more, of the Temple of Solomon; with the arrangement of the Greek and Roman temple, down to the Antonines at the end of the second century of our era, is very remarkable. In the first the parallelogram is preceded by a portico of an irregular number, namely, of five columns. In the second (1012 B. C.) we have the Temple in Antis.

If we enter into particulars, we are still more struck with their correspondence; we find, for instance, the irregular number in the Temple of Jupiter at Agrigentum, one of the largest and most important of antiquity: seven columns compose the front; and we are reminded of Solomon's saying, (Prov. ix.) " Wisdom has builded her house, she has hewn out her seven columns." Again, at Pœstum we have a Temple (miscalled a basilica) with nine columns in the front. Other examples also might be cited. Again, of the Temple of Solomon, that of Themis at Rhamnus, and the frequent temple in Antis. with its pronaos and hieron, is the constant copy. The altar of sacrifice, that of incense, the laver, the table of show-bread, are all traced either in existing remains, in bas-reliefs, or in medals.

The connexion of Sacred and Classic Architecture is thus apparent; and the author of ' The Plagiarisms of the Heathen Detected,' (Mr Wood, of Bath,) is borne out in this comparison of the *plan and arrangement* of temple architecture. The common error (and one to be carefully avoided) is the attempt to trace this resemblance in *the styles*, or the orthographic figure of the parts and orders—the mere vesture of the scheme; and tho failure in straining the texts and examples (Corinthian of Doric) to a perfect correspondence, either in Wood, Villalpandus, or his learned predecessor, Wilkins, has always thrown a doubt upon these interesting investigations; but the comparison of tho *plans* makes the Tabernacle the type of the Greek and Roman temple, a work which Paul as well as Moses assures us was inspired by the Deity, " for see, saith he, that thou make all things according to the pattern showed thee in the mount." (Heb. viii.)

It is remarkable that the earlier or contemporary works of Egypt show no similar arrangement; nor was it likely that Moses should adopt and recommend any form associated with Egyptian recollections. The circular form of plan is indeed traced in Greece, and Rome more especially, and amongst the Druids, but the most frequent by far is the parallelogram, after the Tabernacle: in fact, the earliest inhabitants of the bordering countries were apparently monotheists; their connexion with the Jews through Tyre and Sidon, their respect for a people of superior knowledge and religious instruction, may well have sanctified their form with them: the ritual was the same with them; the idol took the place of the ark; with both, the temple was the Domus Dei; both were religions of sacrifice.

The ritual was thus the originator of the form of the temple, and must always be so. The Temple in Antis became (with a view to ornament, and by the successive inventions for decorum and dignity) the prostyle, peripteral, dipteral, and pseudo-dipteral. The much-boasted beauty of the Greek temple was not, then, an invention of taste, but one of ritual; and in the consideration of Templar architecture, in all times and countries, this important fact must be carefully borne in mind.

Another point of resemblance of classical and Jewish architecture, of great import, since it is the hinge upon which the whole system of ancient architecture turns, is the employment of " costly stones, even great stones, stones of ten cubits, stones of eight cubits." Upon this practice the whole character and taste of sacred and classical architecture depends. The tenth book of Vitruvius treats chiefly on large stones and their transport. The type of the Domus Dei admitted of no extension; the only mode of giving magnificence and dignity to temples, thus circumscribed in form and composition, was by the employment of monolithic masses, and by the exquisite detail of proportion, order, and sculpture bestowed upon them. The ancient world is full of examples of this remarkable principle, and the last and most signal one is that in the Temple at Balbec, by the Antonines, in which three stones measure, in the aggregate, upwards of 199 feet in length.

The Saviour, whose religion was soon to supersede all ancient laws, constantly illustrates his arguments by this practice : "the head stone, the chief of the corner, which the builders rejected," are his constant metaphors ; and his prediction, that of these great stones "there shall not be left one upon another," is literally verified in the subsequent history of Architecture.

Our remarks upon the uniform arrangement of plans of Greek and Roman temples, would be too long, and must be referred to the publications upon them specifically ; but as brought together in this view it may be observed, that the temple at Ephesus, the size of which we learn alone from Pliny, exceeds all others in dimensions, and the constant limitation of length of the great temple to Jupiter especially (at Athens, Agrigentum, Selinus, Balbec, and Rome) to about 358 feet in length, might lead us to suspect the text of Pliny. Vitruvius gives us a few hints of the attachment of the ancients to numbers in his third book, with reference to the dimensions of temples. The investigation of this subject might be attended with curious results. The frequent dimension 358, by the addition of the stylobate, or by the local variation of the foot, may easily be supposed to refer to the number of days in the solar year. In the Temple of the Sun at Palmyra, the portico has 12 columns ; these, added to the columns in the temple, make 52 ; the whole number of columns in the surrounding peribolus is 364. Wren seems to have had reference to this idea in his height of St. Paul's.

The sections of Ægina, the Parthenon, and the temple at Pœstum, exhibit the ancient arrangement of an interior divided into a nave and two aisles, by two rows of columns in double heights ; those of Venus, at Rome, and Balbec, exhibit the Roman form, namely, a vast vault,—in these instances, upwards of sixty feet diameter in masonry. The occupation of the whole of these interiors by the idol, their employment as a vast niche to receive the god (in ivory and gold, at Olympia and Athens), had something of monstrous, but magnificent ; and invested with the art of Phidias, we may understand how even the rough soldier, Paulus Æmilius, might be moved even to tears, as we are told, in the presence of the beauty and majesty of the godhead, as figured by that great master.

Arrived at that period (313 A.D.) in which the Christian religion was adopted by the state, the range of temples now exhibited displays a total reverse of the previous arrangement. The old ritual of external worship and of sacrifice was abrogated. It was now internal and of the heart ; the portions were now enclosed ; a vast area covered with a roof, of which the basilica was the best model, constituted the Christian temple. Upon this the cruciform was engrafted, "in hoc vince," bearing the universal symbol, in plan as well as in every other situation. The theory of the Church of Constantine is handed down to us by Eusebius, bishop of Cæsarea. He describes the church of Tyre [which the Professor exhibited] and many others of his day, with the most interesting and instructive hints as to the signification and arrangement of sacred edifices, which may be very profitably consulted by the architect. The basilicas of St Peter's and that of St Paul's at Rome, in the form of the Latin cross, become the types of the Christian church throughout Western Europe, with very small variation (until the introduction of the dome, which then only modified it), down to the present day.

It was said that 1800 churches and religious structures were built during the reigns of Constantine and Justinian : those of the former were in the basilica form, which is liable to decay ; those of the latter, to which the ritual and other important considerations, gave a new form, resembled the Greek cross of equal lengths. The transept was covered with a large dome, and the ends of the cross with minor ones, forming a group highly favourable to architectural effect. This form, executed in Santa Sophia, became the wonder of the world, and the dome also, 120 feet in diameter, exceeded any executed since the Pantheon at Rome.

The Professor exhibited several Greek churches at Arta, Thessalonica, and other parts of Greece, measured by himself, as also the valuable researches on the Greek Church Architecture of the sixth and seventh centuries, by M. Couchaud, which contained many hints of great beauty and interest to the practical architect. The churches of Russia were all upon this plan. Procopius was the author, who might be consulted with reference to this era of the art.

The dome, which had become the distinguishing feature of the Eastern church, penetrated into Italy, under the exarchate at Ravenna, in the church of Santa Vitali, 510 A.D. ; and again at Venice, in St Mark's, built by a Greek architect (976—1071). Until the eleventh century, the dome formed no part of the western church, except in those instances : it was then that the Pisans, the richest and most commercial people of Italy, began their great church (1063), and adorned the transept with this new feature.

The rivalry of nations is the great fulcrum of many a noble effect, in arts as well as politics ; and to this motive, chiefly, we may attribute the bold scheme of Arnolpho de Lapo, in the church of Santa Maria, at Florence, founded in 1290 ; in which, doubtless, after the model of the Pantheon, he proposed to place a dome, of nearly equal magnitude, over the transept, but raised into the air, in a way hitherto unattempted, except at Constantinople, where, however, the space was one-sixth smaller. But the inveterate and disastrous contests of these republics long deferred the execution, and it was not till one hundred and twenty years after, that Brunelleschi accomplished the work, as related in the very amusing and instructive account by Vasari.

It was just one hundred years after this successful work that Michael Angelo executed the dome of St Peter's, confessedly in imitation of it, as he said himself in contemplating the model—

Vò far la tua sorella,
Più grande già, ma non più bella.

In another one hundred and fifty years, we have the Domes of the Invalides, Val de Grace, at Paris, and St Paul's, in London.

The family of Domes concludes with that of St Genevieve (the Pantheon), and, like the successor of a noble but a worn-out race, exhibits all that meagreness and debility which precedes its extinction.

But the imitations of the types of the basilicas of St Peter's and St Paul's of Rome, in the north and west of Europe,—*more Romano* to the eleventh century, from the eleventh to the sixteenth centuries *more Germanico*, by the societies of Freemasons,—have justly been the admiration of the world, for their unexampled hardihood and practical science, though the remarks on their principles of structure and of art, which the future lectures will have occasion to offer, will show that neither the geometrician nor the scientific architect need regret the impenetrable veil which conceals them. Any detailed discussion of the merits of the plans exhibited would lead beyond the bounds prescribed ; but we must admit that, generally, the continental plans exceed our own in magnificence of design, especially in the double aisles and the western fronts. To what causes may be assigned the more modest design of our own churches, except to that characteristic prudence of our countrymen, which requires the full accomplishment of every enterprise undertaken, it may not be easy to determine ; certain it is, that all the churches of this country are complete in their design and features, whereas those of the continent are very rarely so.

The words of our poet, though not always applicable to architects, unhappily, may be so to our pastors and masters :

When we mean to build, we first survey the plot,
Then draw the model ; which if we find exceeds ability,
What do we then, but draw anew the model in fewer offices.
——— Consult surveyors, know our own estate,
How able such a work to undergo.
Or else we build like those, who half thro' give o'er,
And leave their part created cost
A naked subject to the watery clouds,
And waste for churlish Winter's tyranny.

With reference to the gradual verticality which the sections of the series of ancient and modern temples assumed, we might say, that the earliest were of the earth earthy, and the latter as sublime as the religion for which they were designed. Thus, the height of the Pantheon, at Rome, was equal to its diameter, or as 10 to 10 ; that of Venus, at Rome, was as $12\frac{1}{2}$ to 10 ; that of the Baths of Caracalla, as 14 to 10 ; of St Peter's, at Rome, as 17 to 10 ; of St Paul's, London, 20 to 10, as also of Lincoln ; and that of Cologne was as 34 to 10.

The last great temple of Christendom, was the Magdalene Church at Paris ; it is 325 feet long by 136 feet wide and 126 feet high, and equalled the smaller temple at Balbec. It was the work of more than half a century. In England, great activity had been used in church-building during the last twenty-five years, but the warmest admirers of those zealous efforts could never pretend that any regulated architectural spirit has

directed those works. No church of a monumental character had been attempted. The ascendancy of the high church party is, however, favourable to our art, and it is not unlikely, that under good direction, it may flourish in a few years. But there is much pedantry abroad, and an absence of all originality and intrinsic character in the taste of the day, which leans to the Roman Catholic form, the basilica, suited to a demonstrative form of worship, rather than the auditorium required by our ritual. Veneration for antiquity is to be respected and encouraged, but its transition to superstition is easy. The divines of 1680 have left us models, erected under the direction of Sir C. Wren, which have not been surpassed. Seven of the city churches were exhibited (measured by the Professor), which would be found as remarkable for their adaptation to our form of worship—offering the largest area, with the smallest obstruction to the sight and hearing,—as they were ingenious and admirable in taste and structure.

The favourite design of Sir C. Wren (laid down from the model now in St Paul's,) was also exhibited. It was a precious legacy to posterity, which had never been surpassed in architectural beauty and arrangement, for the Anglo-Protestant Cathedral church, and would probably at some future time be executed.

But attachment to our national architecture may be indulged with great propriety by the adoption of the forms of the Lady Chapels, modified and suited to our ritual—as those of Wells, Ely, and others; or of the chapter-houses; and the Greek church. The basilica form requires length unsuited to our services, and the fragments or curtailed portions of that form, often practised with small success in our recent churches, seem to point at the greater advantage of the vertical arrangement, which the models, the Professor ventured to suggest, in the churches of Wren, and the examples quoted, would assure to us.

The learned Professor then proceeded to offer some remarks on the principal monuments of Civil Architecture amongst the ancients. As ritual prescribed the forms of Sacred Architecture, so political and civil institutions prescribed those of Civil Architecture: where monarchs sway we have their palaces, suited to the temporal governor of earth: regarded as God's vicegerent while living, and as demigods when dead, their mausolea endure through all ages, in the Pyramids, or in the Moles Hadriana; and where these are supported by castes, we have the Labyrinth, the Temple Palace, and the Treasury—in Republics none of these are found, but the Temple, the Gymnasium, the Theatre, the Stoa, the Basilica, and public works abound; when states are absolutely commercial, as Tyre or Carthage, nothing remains but their name in history: their architecture seems to have been confined to the perishable Trireme.

The uncertainty of future existence made duration in the present the earliest object of solicitude; monuments in the pyramid or the obelisk are the most remote architectural works which have reached us. In 1732 B.C. Jacob raised a memorial to Rachel, "that is the pillar upon Rachel's grave unto this day." "The kings of Egypt," says Diodorus Siculus, did not think that the fragility of the body deserved a solid habitation; indeed, they regarded their palaces as simple lodgings, in which each successively inhabited; but they considered their tombs as their peculiar habitations, as their fixed and perpetual domicile."

To the architect, no monument of antiquity could be more precious than the tomb of Absalom, in the valley of Jehosaphat, which is monolithic (for the most part), or rather cut in the living rock, and exhibits an Ionic temple *in antis* (like Solomon's temple), with a Doric entablature, an Egyptian cornice, and a Tholus or circular attic, surmounted with a conical top and a pomegranate; all features in perfect correspondence with the reasonable expectations regarding Jewish architecture, which, however original in *plan* and disposition, would never be so in ornamental style, because the comparative smallness of the nation, the fortunes of individuals limited by law, the agricultural habits of the people, their discouragement of taste, and their position between great and flourishing countries so remarkable for its cultivation as to lend their artists to the Jews whenever occasion demanded, were all opposed to the invention of any peculiar and original style of architecture.

A beautiful representation of this remarkable tomb had appeared in Roberts's 'Holy Land;' there could be no doubt as to its identity, since tradition amongst the Jews on such a point might always be accepted as full and sufficient evidence—its perfect correspondence with holy writ (II Samuel, ch. xviii.) is striking:—" Now Absalom in his lifetime had taken and reared up for himself a pillar, which is in the king's dale: for he said, I have no son to keep my name in remembrance, and he called the pillar after his own name, and it is called unto this day Absalom's place." Wren calls it "the most observable monument of the Tyrian style." "It were to be wished," says he, "some skilful artist would give us the exact dimensions to inches, by which we might have a true idea of the ancient Tyrian manner."

Labyrinths are amongst the earliest and most astonishing of architectural works; they were found in Egypt, Crete, Lemnos, and Tuscany. Herodotus describes them as surpassing in extent and magnificence: the one he describes (Eut. cxlviii.) was composed of twelve courts, having apartments of two kinds, fifteen hundred above the surface of the ground and as many beneath, in which were the tombs of their kings. "No one could enter them," says Diodorus Siculus, "without a guide." Yet Pliny tells us they were not contrived like the ornament commonly called by that name; in that of Lemnos, says he, were 150 columns turned in a lathe, which a child could move; and this is remarkable as evidence of the use of such a machine in the capitals of the Parthenon, which has been always supposed.

The living use of the Labyrinth is left to conjecture; but we may easily conceive its adaptation to a people of castes, with whom it might be colleges for those aristocratic classes surrounding the throne. We are told that all the youth of Egypt, born on the same day with Sesostris, were set apart and educated with the young prince, and thus it was that he found himself surrounded in manhood by attached companions, who carried his conquests and his fame to the greatest height. Where could so vast a generation be educated but in the Labyrinth?

The Professor doubted the interpretation commonly applied to the so called temples of Egypt; he believed them to be rather temple palaces, in which the temporal administration of a great country was carried on, together with the spiritual. The ruins of Karnac covered ten acres. Within the walls was enclosed a space equal to the whole length of St James's Street, and four times its width. The comparison of this plan with that of the Louvre and its courts, with the use of which we are familiar (and exhibited with plans of Luxor and Dendera, and Diocletian's palace, and others drawn to the same scale), would show the high improbability of the employment of such vast spaces for the priesthood alone; and it could be shown, especially at Dendera, that all the public business of the realm might be conducted there, and that the Pharaoh himself very probably resided, as in the Arab villages at this day, upon the broad terraces which these vast buildings afforded, raised into the air, and removed from the vermin, inundations, mirage, and confinement, to which the habitations on the soil of Egypt were subject.

The Pharaoh united the offices of monarch and high priest, and all the dignity and imposing awe which the arts could afford, were associated with his presence. The palace was approached through an avenue of sphynxes of a mile in length. The Pylæ were seen afar off raising a vast front of uniform surface, on which were engraved on one side the Pharaoh in his warlike attributes reviewing his troops, charging the enemy whom he annihilates at a stroke, besieging cities; on the other, he is peacefully administering justice, and the more sacred duties of his priestly office. In front of this were obelisks (the smallest of which is now in Paris), and colossal figures of the Pharaohs.

The first court equals in size Waterloo Place, from the column to Pall Mall. Here, under a colonnade, "the King sat in the gate," with "his princes and counsellors;" this was "his porch of judgment;" the sculpture and painting of the ceiling symbolized appropriately the passage of the soul through human vicissitudes to a final judgment.

The columnar grove beyond, 325 feet by 266, afforded a waiting hall (the only cool one in Egypt) for all the court, so pompously described in Daniel: "the princes, the governors, the captains, the judges, the treasurers, the counsellors, the sheriffs, and the rulers of the provinces." Through these was the approach to the Sekos for the god; and on the face of each column of the avenue were represented on one side Osiris, on the other the Pharaoh.

The paving above all this showed a surface prepared for other buildings, apparently of timber: holes occur for the reception of the posts, very large ornamental spouts for the discharge of sewerage and water, IN A COUNTRY OF NO RAIN, and therefore only wanted for the uses of a great family. The parapet walls forming the external face of the Temple Palace, surmounted with the usual

cornice, defend and partially conceal these buildings; and at Dendera especially are chapels for the daily services of the Pharaoh and his family on this high level, and the staircases by which they arrived at them. These were the "*ivory palaces*," the habitations of cedar, and sandal, and almug woods, alluded to in the 45th Psalm, and in which each Pharaoh might indulge his taste, and be "*glad*," and enjoy exemption from the inconveniences of the nether world.

The Treasuries of Atreus, forty-eight feet in diameter, and the gates of Mycenæ, and the Treasury of Orchomenos, of still larger diameter, are the only monuments of Homeric pretension, unless the Lycian remains, discovered by Mr Fellows, can be proved to be of that remote period, and that the taste of Sarpedon can be identified by them.

Amongst the objects of Civil Architecture, few have had more influence on the art than Theatres both in their external elevation, in the application of the orders in relief on the pier and spandrel of the arch, and in the internal elevation, the scene, which has been the occasion of so much caprice and corruption of taste. The theatre, being constantly employed for parliamentary assemblies, required a permanent scene; as well as one moveable, and adapted to the performance. It was a subject of vast architectural study and expense. Pliny (lib. xxxvi.) tells us that Caius Antonius silvered the scene; Petronius gilt it; Quintus Catullus clothed it in ivory. Scaurus surpassed them all; he raised 360 columns, in three ranges: the first was of marble, 38 feet high, the next was in glass, the third of wood gilt. 3,000 bronze statues ornamented the intercolumniations. Curion, unable to surpass Scaurus, built two theatres of wood, which, being back to back, could be turned so as to form an amphitheatre for gladiators, displaying the skill of the Roman carpenters to great advantage.

Palladio's scene of the Theatre at Vicenza gives the best idea of this feature of ancient architectural magnificence.

Originally of wood, and continuing so for many centuries, it was not until the third century before our era (232 B.C., the Theatre at Epidaurus,) that theatres were built in stone and marble. The Greek theatre approached the amphitheatre, and was a horse-shoe comprising 200° or more, because the orchestra was reserved also for the performance; but the Roman theatre did not exceed 180°, because the orchestra was occupied by the senators.

The Odeum was a covered theatre, chiefly for music; that of Herodes Atticus, at Athens, was the most magnificent in Greece, and had a roof of cedar. The space covered was 240 feet by 159. The construction of such a roof, without obstructing sight or hearing, or injuring external architecture, offers a problem to the architect of no easy solution, and is one of great interest in the present times, as we are frequently called upon to cover large areas for occasional assemblies.

But as modern theatres were more to the point with students, the Professor called their attention to a magnificent work, lately published, on "The Great Modern Theatres of Europe," by M. Contant.

The Amphitheatre was then considered: although of early Tuscan origin, and originally formed in earth or scaffolding, was not executed in permanent materials till the end of the first century. One in earth was discovered by Sir C. Wren at Dorchester. That of Vespasian (as shown in a diagram) was too large for the site of Trafalgar Square, Charing Cross, &c. The Velarium, 550 feet by 450, with which the Colosseum was covered during exhibitions, was a surprising contrivance, and had been made the subject of a work by the architect Fontana. M. Hittorf had suspended the roof of a panorama in the Champs Elysées, somewhat in the manner of the Velarium, with great skill.

The Gymnasium, in which the youth of Greece were instructed for the defence and honour of their country, in every department of prowess, is an interesting object of civil architecture. The plan of that of Ephesus, has been published by the Dillettante Society, (exhibited,) and it is gratifying to observe the use which the late Professor Mr Wilkins has made of this example, in illustration of the text of Vitruvius, which had before been misunderstood.

The Gymnasium is the more interesting as the type of those Thermæ, the Roman baths, which have furnished the great school of architectural instruction, and from which the best inventions of the architects of the Middle Age, and of the revival, have been derived.

The name, Thermæ, as well as the express declaration of Vitruvius, declare that these institutions were exotic: a refinement adopted from Greece in the time of Augustus. During the first three centuries of our era, seven of these were erected; they were well calculated to indulge that love of luxury which rapidly corrupted the Roman manners under the Emperors, as well as to gratify that constant excitement of novelty and splendour, which gave popularity to the government. Some idea of their extent may be conceived from the plan (exhibited) of the Baths of Caracalla laid down upon that plot which is comprised between Regent Street, Pall Mall, St James's Street, and Piccadilly, covering about twenty-eight acres. Cameron assures us that those of Diocletian, somewhat larger, afforded hot baths for 18,000 persons at the same time: a bell rung at two o'clock to announce that the water was warm. The mask of a paternal urbanity was often affected by the despotic emperors, who frequently bathed with the people. One day Hadrian recognized an old companion in arms in poverty, scraping himself with a tile instead of the strigil; accosting him kindly, he furnished him with a slave, and all that could be wanted to his future comfort. Such an example could not but be infectious: accordingly when he came again, he was surrounded with poor acquaintances scraping themselves with tiles; but, calling them together, he observed, that being many they could scrape each other, without any superfluous expense of slaves or furniture. The Thermæ were in fact vast clubs, castles of indolence, in which every easy exercise of body or mind, and every delight of the senses might be indulged. The gardens, raised about thirty feet above the general level, were adorned with every fragrant shrub and flower; the choicest works of sculpture, obelisks and fountains, exedræ for the enjoyment of the shade or the sun (of a structure well worthy the student's attention) terminated the walks. In the central building was the great hall, the type of Gothic structure in ecclesiastical architecture, namely, the groined ceiling reposing on a column, and abutting on an extended pier, with the nascent flying buttress. The space of the naves (varying from 76 to 90 feet) being twice that of York, the widest of our cathedrals. The area covered offers the largest space with the smallest obstruction in the support of any scheme yet devised, and cannot be too much admired. It has been well observed of those structures, that we discern in them the type of all that has been since done in architecture, just as throughout the animal creation we trace the more or less resemblance to the type man. The interest excited amongst the French students recently (as exhibited in their late competition for the grand prize), promises that this admirable feature of ancient architecture will be reproduced in Europe before many years pass. It was proposed for the new Public Library at Cambridge; it was employed by Sir C. Wren in Bow Church, on a small scale; and is executed on a still smaller scale, with considerable differences, but with happy application, in the Bank of England, by Sir J. Soane. But the cloisters, the surrounding rooms and baths, their various forms and structures, and the happy union of the arch and the trabeated systems, would lead to more observation than can be here admitted. Palladio designed to have published a book upon them, the drawings for which were afterwards edited by Lord Burlington. Mons. Blouet has published a magnificent work, giving all the restorations and details, which large excavations and very careful study of them enabled him to obtain.

The Basilica is also of Greek origin, as the name imports. The kingly hall was such as Solomon built in the palace of the forest of Lebanon. It was the Westminster Hall of ancient governments for administration of justice, commercial exchange, great public meetings, &c. The building at Pœstum, so called, was more probably a temple, because the Greeks were not accustomed to apply sacred architecture to civil purposes.

The Basilica of Trajan was the most magnificent exemplar of this species of building which the Professor could point out: with its forum, temples, and approaches, it covered twelve acres. The central hall or basilica, 540 by 168 feet, would contain St Paul's in length and in width, exceeded only in the extreme ends of the cross. The central nave, 278 by 78, would contain the whole of Westminster Hall, in plan as well as in section. In Rome were eighteen basilicas, and one at least in every city of the empire. Their subsequent adaptation to the Christian temple makes them highly interesting to the student. Vitruvius, (lib. v. c. 1,) describes the basilica, and his own work at Fanum, which differs from the usual form in some particulars.

LECTURES ON SCULPTURE.

By Sir Richard Westmacott.

LECTURE II.

THE ARCHAIC PERIOD—BLOCK STATUES—FIRST AGE OF GREEK ART—EARLY FORMS ON COINS—GRADUAL IMPROVEMENT IN SCULPTURE—THE ÆGINETANS—RUINS OF THE TEMPLE OF JUPITER PANHELLENIUS—INFLUENCE OF RELIGION AND HEROIC ACHIEVEMENTS ON ART.

Sir R. Westmacott's second lecture embraced a general survey of the schools and style of art of and from the earliest, or *archaic*, period, down to the fifth century before Christ; the age of Pericles, and of Myron, Phidias, and Polycletus. The professor in his introduction adverted to the primary object or application of sculptured forms, and remarked how that circumstance influenced the style or sentiment of the artists. The purpose of the first emblematic representations in all countries being, he said, to present to the people objects of public worship, the spirit which invented them became transferred to Art. With some nations, as with the Egyptians, this representation could only be effected under certain forms established by custom or by law. The same obstruction to improvement (for it had that effect) existed in more eastern countries; and it may be traced even in the early periods of Rome. With the Greeks, also, a high degree of veneration for ancient types continued for some time after they had arrived at comparative eminence in art; but when the rapid progress in civilization of this highly gifted people had produced its natural effects, both in their physical and moral condition, their ideas respecting art experienced, also, a revolution, and, as will be seen as we proceed in our examination, they substituted more pleasing forms for the hitherto prescriptive characters of their divinities; and while they rejected or modified the old symbols, they sought in nature for the character most accordant with their ideas of fitness with relation to the personification proposed.

The first types of their divinities were mere blocks. Thus we find Jupiter Milichius was worshipped under the form of a pyramid; and Diana Patroa, and the ancient Venus of Paphos, were represented by rude columns; to these, heads were shortly after added. The Lacedæmonians retained this practice for a long time, and Pausanias speaks of a Venus Urania of that early style of art preserved at Athens in his time.

Figures, with the arms attached to the body, in the Egyptian manner, followed next; the separation of the lower extremities being marked by a mere line; but at what time the formation or development of the whole figure, with action, took place is uncertain.

This extremely rude art appears to have continued until about 800 years B. C., when Dibutades of Sicyon is supposed to have formed his school. The statues of that time, from the custom of exhibiting figures at festivals, were draped, and we have most probably a fair specimen of their simple construction and treatment in a fragment of a draped statue now in the British Museum. It is from the temple presumed to have been dedicated to Themis, at Rhamnus. It must be admitted, however, that the foundation of the schools of Sicyon, Corinth, and Ægina, is involved in much obscurity. The most authentic examples of archaic art and style are to be found in coins and medals.

It would not be difficult, perhaps, to trace the causes of the changes in Art; to distinguish the passions or motives which influenced these changes; and to see how far imagination swayed the artist in this respect. In recurring to the history of the people amongst whom the arts were most successfully cultivated, we shall find that the departures that were made from ancient usage arose from no light or unsteady desires,—from no inconsistency or indifference to the Arts in the mass of the people, but from a sense of their religious and political importance, combined with the personal feeling of the artist, who desired to have scope for the full development of his powers; and the time arrived when a nation felt that its glory was as immediately connected with the fame of its artists, as with that of its historians and its poets.

The first period of Greek art, that is, from the 30th Olympiad to the age of Ageledas, was distinguished in its earliest stage by the same peculiarities in the eyes, countenance, and general forms which I have noticed in the early period of Etruscan Art. The earliest Athenian tetradrachms, as well as the coins of Posidonia, Caulonia, and some others, the character of which is eminently deficient in variety and expression, supply examples of this period.

The more ancient temples of Greece, and the statues within them, having been utterly destroyed in the Persian invasion, medals, from the symbols found on them, not only assist in making us acquainted with the ideas entertained of art in those towns where they were struck, but they often lead to the knowledge of statues, and other works now lost, and also of the epochs in which they were executed. The professor took occasion to observe that, as the Mint was in many cities wholly under the control of the priesthood, a long adherence to archaic form was secured, even after the twin branch of Sculpture had considerably improved. Indeed, the respect paid by the Greeks themselves to early emblems, frequently led them to preserve these forms on their coins, in preference to imitating on them their own beautiful statues.

It is remarkable that the faculty of seeing and boldly copying nature is strongly indicated in the coins of Sybaris, which are even of an earlier date than those of Posidonia and Caulonia. In the Bull, which appears on the reverse of these coins, the hind quarters of the animal are treated in a very grand and effective manner, and the whole is executed with surprising freedom.

From the necessity of adapting both alto and basso relievo to their coins, these works present notions of just proportions at a very early period of art. The best specimens of the kind in this country (speaking of works in low relief,) may be seen in a subject representing "Hercules taming the Hind," and in one of the "Dioscuri curbing a Horse." They present a quality of relievo which has been successfully adopted in a later age, for works in particular situations. An interesting example, in marble, may be seen at Wilton House. This very curious basso-relievo has on it an inscription in the Boustropheden manner.

The style of this early period is rigid, and there are peculiarities which distinguish it in a marked manner from that of later ages. The muscles, more especially of the body, are more strongly indicated than they appear in nature; but they are accurately disposed. The proportions are long, sometimes extending to eight heads, the chest is full, and the lower part of the abdomen contracted, while the thighs are much charged or swollen. This style continued so late as 500 B. C.

Thus, from the examples preserved to us of bassi-relievi, and with the aid of medals and coins, we may form a tolerably just estimate of the state of Hellenic Art, for several ages,—from the rude to the more enlarged view of nature, until the principles of style became fully established at about 525 B. C.—the age of Canachus and Aristocles, the heads of the School of Sicyon,—and of Ageledas the master of Phidias, of Myron, and of Polycletus.

Art, even in the most adverse times, when Greece was disturbed by various foreign irruptions, but more particularly by the check given to its prosperity by the Dorian Invasion, was still supported by Religion; and although slow in its progress, it was never, as with their literature, wholly interrupted. Their statues, at earlier periods of art, were usually of wood or clay, or in what is called Toreutic Art. But the Professor remarked that Pausanias mentions having seen at Lacedæmon a statue in brass by Gitiadas, whom some antiquaries place at 750 B. C.; and another by Learchus, of Rhegium, said to be the oldest existing in that material. They were of hammered work, and rivetted, and, most probably, were—so called—Dædalian Art.

There are also some statues in marble of the above period. The colossal head of Hercules in the British Museum, with crisped locks of hair, is of the same style. The Professor's opinion of this work is, that it is a copy from a bronze of an earlier period. This head has, however, other peculiarities than those common to art of its supposed age, in the double marking to the upper eyelids. The coins of Acanthus of this period are remarkable for their beauty and intelligence, as are also those of Ænos and of Thasos.

It must be observed that, imperfect as are these examples, they were the germ of those principles which were preserved to succeeding ages. Thus we find, at a very early period, when the free study of nature was still fettered in Greece, (the fine

arts being under the control of hieratic laws,) that the artists established certain principal divisions of the body; this was soon followed by the extension of the masses and the more correct marking of the muscles; the union with the adjacent parts was observed, and much attention was given to the termination of the bones, and their appearance as indicated in nature. Though we still find no direct attempt at beauty, there was a more exact consideration as to parts; and though the treatment or execution was angular and severe, both in statues and in works in relievi, the drawing generally was more correct.

We now approach a period when civil institutions became more settled, and science and literature had begun to enlarge the mind. The Greeks perceived that something more was required than the mere imitation of nature, but they had not yet arrived at that degree of confidence which stimulated them to follow immediately the impulses of genius, though many of their works clearly show that they were struggling for more noble objects and a wider range.

Before I proceed to consider the style of the immediate precursors of Phidias, and their reputed works, I shall advert, as they more properly belong to the Archaic Age, to the discoveries among the ruins of the temple of Jupiter Panhellenius, in the island of Ægina.

Of the artists who constructed this temple, or who executed the sculpture, we are uninformed. We may, however, from the high character of the people, and from the veneration in which the Panhellenian god was held, reasonably conclude that the most celebrated artists of the age were employed in the execution of these sculptures. Callon was at this time in great repute, as was also Canachus; and Ageledas, then in his noviciate, worked under them. This was about 535 B. C.

The Æginetans had long held a distinguished place, both as a commercial and a refined people, among the other nations of Greece. The Athenians, jealous of their reputation and increasing naval power, sought by exclusive decrees a cause of quarrel, which ultimately led to the captivity and dispersion of the weaker state. After the battle of Ægos Potamos, and the termination of the Peloponnesian War, 405, B. C., the Æginetans were allowed to return to their island, but they never again rose to any great consideration or power.

The dispersion of a school which had been held in such high esteem, and in which it may be said Myron, Polycletus, and Phidias, were formed, must have had considerable influence on the people with whom they had colonized, and must have contributed generally to the establishment of sound principles in art. In the marbles to which I have alluded, the peculiarities of the early manner are not only subdued, but a striking attention to nature may be observed in the bodies, the arms, and the lower extremities, while the heads and the hair have all the peculiar and distinctive character of the symbolical and prescriptive sculpture of the remote Archaic period.

It will not be very difficult to account for this discrepancy and seeming inconsistency. Typical Sculpture, as the Professor had before remarked, was preserved (in coins more particularly) long after considerable progress had been made in art. With the Æginetans there were most powerful reasons for its being more especially preserved. Proud of their lineage, and their direct descent from the Æacidæ, they remained strongly attached to every idea connected with their local deities, or with forms which conduced to the remembrance of the heroes from whom they sprung; and the respect in which these (the Æacidæ) were held throughout Greece, induces a strong belief that these marbles present typical images; perhaps of Telamon, of Peleus, of Achilles, and Pyrrhus, ancestors of the Æginetans, and the memory of whose heroic actions they must have been particularly anxious to preserve.

The heads, which afford subject for the antiquary, rather than the artist, have all the peculiarities of the most ancient period; but the eyes protrude, and are rather full on the profile; the mouth is a little open, the terminations turning upwards, giving the expression of a constant smile; the chin is large and pointed, the hair on the heads, beards, and on the pubis, is disposed in a regular order, in small and crisp locks. To several of the helmets metal ornaments were attached.

In these marbles we may perhaps trace the last examples of the early consecrated form in the heads of divinities and heroes; though later artists imitated the style of Etruscan statues, and we are told that Euticrates, the son and scholar of Lysippus, preferred the austerity of preceding masters to the elegance of his father's works; and thus we still find, even in the soft age of Praxiteles, examples of the more severe manner of Myron. But it was no longer a prescribed system of representation from which artists could not depart.

An example may be seen of the style of art immediately preceding the age of Phidias, in a statue of Apollo in the British Museum. From the description left us by Pliny and others, it affords us a fair idea of the style of Onatas. Though it is hard and severe, it has much grandeur and vigour, and there is in it an approach to ideal grace, and a more careful imitation of nature: we may still, however, trace, both in the treatment of the head, and in the thighs, some of the characteristics of archaic art

Among the works which immediately preceded the most splendid era of Sculpture, may also be classed the marble statue of the Discobolus, or Quoit-thrower, of the British Museum; an ancient copy from the celebrated statue in bronze, by Myron. This statue, it must be observed, offers in its composition one of the very few examples preserved to us in the antique of statues in violent action.

The Professor here alluded to the great advantage which accrued to art from its extensive employment in decorating temples, and in recording the heroic deeds of the Athenians. The defeat of the Persians had as extraordinary an effect on the arts as on politics. The enterprising spirit of the Athenians received every possible stimulus to exertion, and the aid of art was called in to do honour to noble and patriotic achievements. This gave ample employment to the sculptor, while religion became sufficiently indemnified for the departure from the old consecrated forms, in the almost superhuman excellence which characterized art in the representation of gods and heroes, and in the surpassing splendour of chrys-elephantine Sculpture, or the combination of ivory and gold.

To name all the distinguished sculptors and statuaries of this period, would offer a mere catalogue without any very useful application. It will be sufficient to say, that this age was graced by Phidias, Alcamenes, and Agoracritus, and embracing a period of fifty years, by Polycletus, Gorgias, Myron, Scopas, and Pythagoras. Under these artists, or at about 430 years B. C., sculpture may be said to have reached its acme.

HISTORICAL NOTICE ON LEVELLING INSTRUMENTS: WITH DESCRIPTIONS OF IMPROVED INSTRUMENTS FOR LEVELLING.

Huygens, in the seventeenth century, appears to have been the first to *apply the telescope to a level* of his, which was constructed on the principle of the plummet. The honour of having first applied the *air-bubble* to the determination of horizontality seems to be due to Dr Hooke. The inventor of the *circular level* is not certainly known; but Switzer, in his Treatise on Waterworks, which was published in 1734, remarks, that the circular level was then employed in the construction of the surveying instrument called a plane-table. According to Sir John Herschel, the *cross-hair*, which gives so much accuracy to all astronomical, as well as levelling instruments, was the invention of Gascoigne, a young Englishman, who used it in 1640. M. Le Bion appears to have been the first to *conjoin the telescope of Huygens with the air-bubble* of Dr Hooke; and this must have been subsequent to the year 1684, as such an instrument is not shown in De La Hire's edition of Picard's Treatise on Levelling.

But it was not till Sisson's improvements that the level could be considered as in any way an accurate or philosophic instrument. All that were made previous to his time were coarse instruments, adjusted by a ball and socket, and in other respects resembling the common perambulatory survey-level, which, from the nature of the construction, can be levelled in only one direction, and cannot be reversed, or moved even in the slightest degree, without requiring readjustment. Sisson may, therefore, be considered as the inventor of the instrument in common use The main feature in his improvements was the introduction of four screws called the *parallel plate screws*. The date of Sisson's improvement is not known; it is simply noticed in Switzer's System of Water-Works.

Since the time of Sisson, the celebrated Ramsden introduced a tangent-screw and clamp, for moving the instrument with accuracy through small distances in an azimuthal direction. Messrs Troughton and Simms also made several improvements in the arrangement of the various parts of the instrument; and Mr Gravatt has of late years added a cross-bubble for facilitating the *rough-setting* of the instrument—or that adjustment which is made with the legs of the tripod; and an enlargement of the diameter of the object-glass, so as, by the admission of a greater number of rays of light, to allow of the telescope being shortened without impairing its optical powers.

The annexed figures represent the Portable Levelling Instruments invented by Mr David Stevenson, Civil Engineer, Edinburgh, drawn to a scale of one-third of the original size. They are thus described by the inventor :—

The level, figs. 1 and 2, consists of an accurate spirit-level,

Fig. 1.

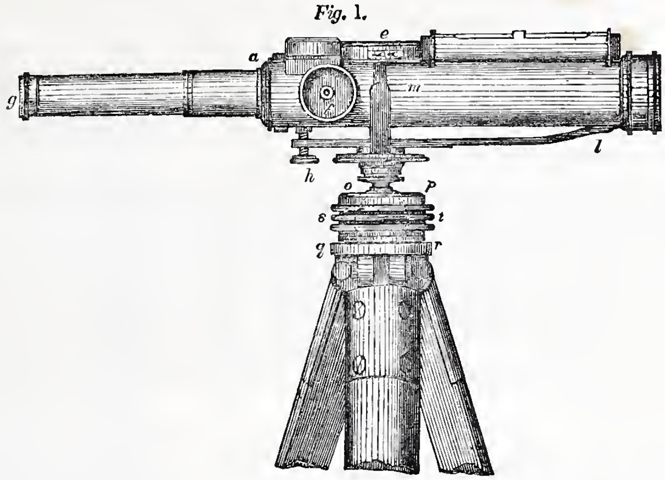


Fig. 2.

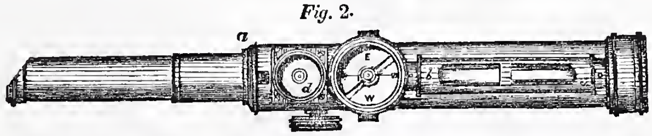


Fig. 3.

Fig. 4.

Fig. 5.

a 10-inch telescope, and a compass, so arranged as to admit of being very portable. The telescope unscrews at a, so as to form two compartments, and the whole is packed in a pocket case measuring 6 by $2\frac{3}{4}$ inches; and the tripod on which it stands does not exceed the bulk of a thick walking-staff.

Referring to the drawing; $b\ c$ is the level; d, a circular level; e, the compass; f, the screw for adjusting focus; g, the eye-piece; h, the screw acting on the spring l, which is fixed to the telescope at m, by a crutch on which it moves; n, the screw by which it is fixed to the tripod; $o\ p\ q\ r$, the top of the tripod, which contains a ball-and-socket joint, shown in dotted lines, which can be clamped and unclamped by means of a screw wrought on the inside of the part $s\ t$. In setting the instrument, the screw $s\ t$ is first unclamped, and the instrument is moved by the hand on the ball-and-socket joint until the air-bubble of the level d occupies the centre of the circular box containing it. The screw $s\ t$ is then clamped, and the instrument being directed to the object to be observed, the final and more perfect adjustment is made by bringing the air-bubble $b\ c$ to occupy the centre of its tube, which is done by means of the screw h, which acts on the spring $k\ l$. The tripod is that used by Dollond for the camera lucida, and answers both instruments. The telescope can be made either, as in ordinary levels, to reverse the objects, or, as in theodolites, to show them in their true positions. In this level, made for myself, I have adopted the latter construction, in order that the instrument may answer more perfectly the purposes of a field telescope. The addition of the compass is also a further convenience.

In connection with this instrument, Mr S. had also a portable levelling staff made, which is represented by figs. 3, 4, 5. It consists of an elliptically-moulded staff, three feet three inches in length, and cut through the middle; the two halves are hinged at one extremity, and when unfolded, are fixed by a spring, forming a rod six feet six inches long, on the flat side of which the graduations of feet and inches are painted; when closed, the graduation is protected from injury, and the whole forms a convenient walking-staff.

It will be observed that a circular or, more correctly, a *spherical*, level is introduced into the instrument, figs. 1 and 2, instead of the small cross-level, which was introduced by Mr Gravatt. The advantage of the circular level over the common form, is its peculiarity in at once showing the deviation of the instrument from horizontality in both directions, instead of only one.

Again, the clumsiness of the common level consists in its be-

ing at all dependent on the setting of the legs. This arises from its being controlled in its action by the parallel plate-screws of Sisson, the consequence of which is, that in using the common level, care must be taken to set the instrument very nearly level *by the eye*, so as to be within the range of the parallel plate-screws, otherwise it is impossible to adjust the instrument. And although to the practical man, the trouble attending this may be comparatively small, still he will admit that it is one of the most irksome parts of the whole operation of levelling, to say nothing of the time that is lost in adjusting the instrument afterwards with the parallel plate-screws. What appeared to be wanting was a motion for the preliminary, or *rough-setting*, intermediate in nicety between those of the parallel plate-screws and of the legs. To this end, the ball-and-socket motion *o p* is unconfined by the plate-screws, and renders the instrument readily adjustable to the inequalities of the ground.

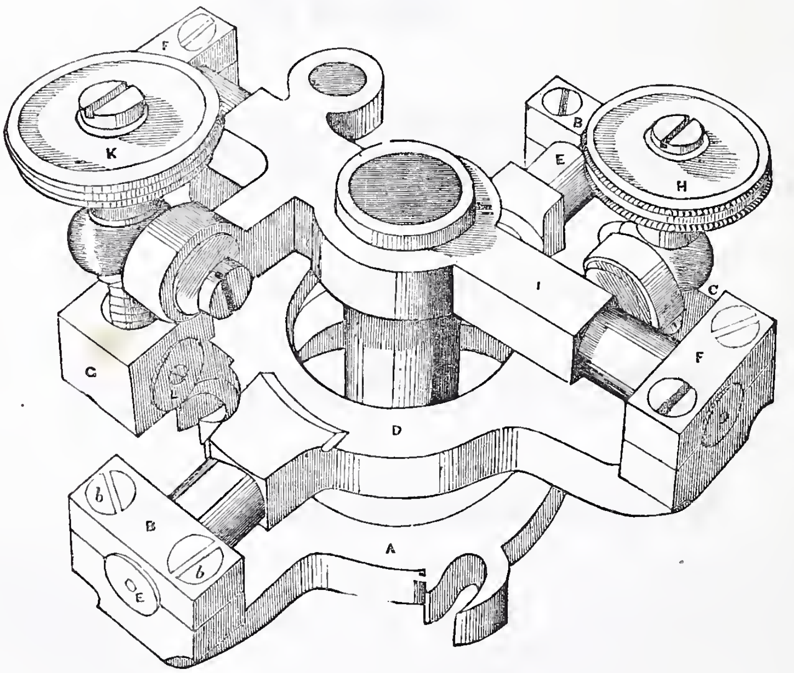
In levelling over mountainous districts, it very often happens that it is desirable to select a station where the ground is so rugged and precipitous as to render it difficult, if not impossible, to find three points for the extremities of the legs of the instrument to rest on, which shall be on such levels as to bring the telescope within the range of the parallel plate-screws; but wherever the instrument can be made to stand with safety, the bubble of the improved level can be adjusted, and adjusted in exactly the same time, and with exactly the same ease, as if the instrument were placed on level ground.

Another advantage, says Mr T. Stevenson, of these improvements, is the removal of a great practical difficulty which is often experienced on sloping ground. The instrument being set and properly adjusted, the observer, on looking through the telescope, may discover that he is not within the range of the levelling-staff; in other words, he has chosen a station too high or too low to admit of his seeing any part of the staff within the field of the object-glass. The only remedy for this is to choose a new station where the instrument must be again set up and levelled, at a great expense of time and trouble. In order to remedy this, it was my intention at one time to have fixed on the telescope a French level, on the principle of the plummet, in order speedily to discover, before making the adjustments, whether the intended station were within the range of the staff or not. But the instrument can be roughly set with so much quickness by means of the additional ball and socket, that the French plummet may be considered as being now scarcely necessary.

The following apparatus was contrived by Mr John Sang, of Kirkaldy, and is intended for levelling small theodolites, as a substitute for the parallel plate-screws. Only one hand is required to regulate each level, and the instrument is kept steady without tightening the screws, so that both levels can be adjusted at the same time, and more rapidly. It gives the same facility as the apparatus of three screws, sometimes applied to large instruments, whose weight is enough to resist shaking in azimuth

A (fig. 6) is a part made fast to the legs of the instrument. It has two sockets at B B, and a box at C for holding a cylinder

Fig. 6.



containing a screw-nut. The box C is not well seen in the drawing; it is similar to the other one marked G.

The part D has an axis E, working in the sockets B B; each end of the axis is a double cone, carefully fitted into the sockets, and tempered by the screws *b b*. It has, at right angles to this axis, two sockets F F similar to those in the lower part, and it has also a box at G, holding a cylinder containing a screw-nut.

The screw H is attached to the part D by means of a revolving joint, and it works in the nut at C, so that, on being turned, it alters the inclination of the part D to the fixed part A.

The part I, which contains the outer axis of the theodolite, has an axis (like E) working in the sockets F F.

The screw K, working in the nut at G, and being attached to the part I by a revolving joint, alters the inclination of I with regard to D, so that, by means of the two screws H and K, the part I can be inclined in any manner to the fixed part A, while there is in every portion of the apparatus a firm resistance to a motion in azimuth.

The small screw L is intended to temper the pressure of a piece of tin, inserted into the nut to make up for the wearing of the levelling screw.

This apparatus will add to the expense of a theodolite, but by no means in proportion to the time which it will save.

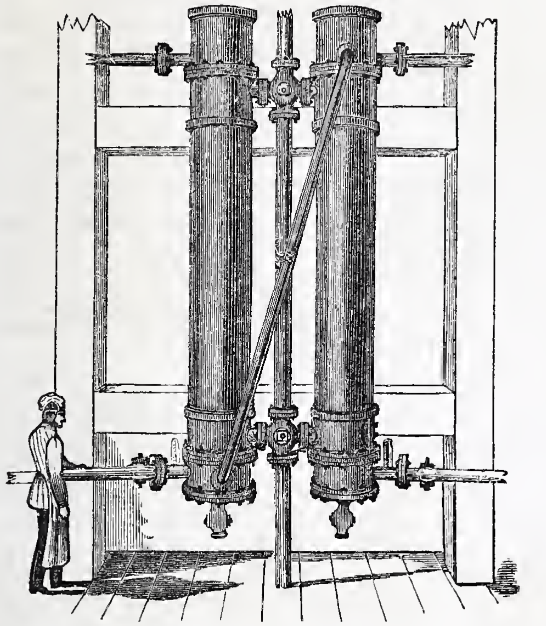
MASTERMANS PATENT REFRIGERATOR.

This Refrigerator possesses several advantages over most others.

In comparison with the cost of construction, its power of refrigeration is *superior*, notwithstanding that *a much less quantity of cold water is employed.* The space occupied is considerably less: and there are greater facilities for cleansing.

It is applicable to the cooling of any liquid; but, in the following details, it will be considered as in use for cooling wort, in a brewery or distillery.

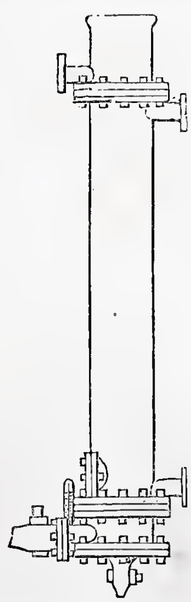
No. 1.



Three forms of the Refrigerator are here represented.

The second, or No. 2, consists of three hollow cylinders of cast-iron, joined together by flanges and screw bolts, and fixed in a perpendicular position, a plate of metal being interposed between each of the two joints. The middle cylinder, with the two plates, forms what is designated "the case;" it encloses an aggregation of small, straight, and very thin brass tubes, eligible dimensions for which are, 12-ft. in length and ½ an inch in bore; their ends pass through corresponding holes in the two plates, which holes are made water-tight around them. The upper cylinder forms an open-topped feeding cistern for the tubes, the orifices of which open into it; the lower cylinder, (its bottom being closed by a plate of cast-iron) forms what is designated "the receiver," into which the lower orifices of all the tubes open. A cock is fixed in the bottom of this receiver for the purpose of drawing off the wort remaining in the Refrigerator after use, and also the water run into the cistern immediately afterwards, to cleanse it, the tubes, and the receiver. The tubes in the case are thus arranged—one in the centre, and the remainder equidistant, in the circumferences of concentric circles, described from the centre; six tubes being placed in the smallest circle, and six being added progressively to each circle.

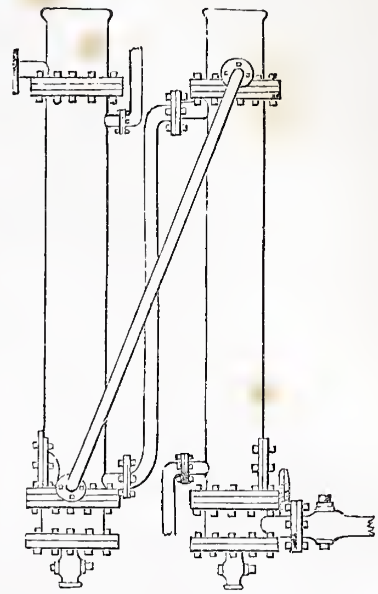
A case, having the inner diameter of 12 inches, will contain 127 such tubes; one of 13½ inches, 169; and one of 15 inches, 217.



No. 2.

The mode of operating with No. 2, is as follows:—The cold water flows into the case through the lateral pipe near its bottom, and rising therein outside the tubes, is discharged through that near its top. The wort flows into the cistern by its lateral pipe, descends through the tubes into the receiver, and is discharged therefrom by its lateral pipe at the required temperature, which is ascertained by a thermometer whose bulb is inserted in the discharging pipe, the discharge being regulated by a cock in the same pipe.

The third form, or No. 3, consists of two parts, each similar in construction to No. 2, and connected by pipes in such a manner that the cold water ascends in each of the cases, successively, and the wort flows in a contrary course, through both sets of tubes, also successively.



No. 3.

The first form, or No. 1, is similar to No. 3, with the addition of certain pipes and cocks, by means of which, and by merely turning the spigots of the cocks to appropriate positions, the two parts may be used either jointly, as No. 3, or separately as two refrigerators, similar to No. 2, or one of the parts may be used to the exclusion of the other.

The directions assigned to the currents of wort and cold water, will (on account of the changes of specific gravity in each, consequent on the variations of their temperatures) induce a tendency to prevent any portion of the warmer wort and water above from mingling with the cooler wort and water beneath, as they respectively ascend and descend through the cases and tubes. The descending course of the currents of wort through the tubes also tends to cause it to be discharged from each of them into the receiver at precisely the same temperature, notwithstanding the tubes may severally differ in their power of transmitting heat; any other direction of either or of both of these currents would, in a greater or less degree, counteract these beneficial results. The cylindrical form and small diameter of the tubes, give a maximum strength to an extremely thin substance of metal, and the large number of the tubes collectively presents a very extensive surface; their perpendicular position, moreover, and the direction of the currents of the two fluids, cause the coldest portion of the water to be applied to the coolest portion of the wort. The principles thus brought into co-operation, and worked out to their utmost practical results in the construction of this refrigerator, ensure to it the greatest attainable cooling power, where cold water is used as the means of extracting the heat. In fact, experience has proved its power to be so considerable, even when the refrigeration is commenced at a high temperature, and the quantity of cold water employed is comparatively small, that the usual area of coolers may safely be reduced to one half; consequently space is gained; and there is saved, besides outlay in the coolers, much of the waste of wort occasioned by the absorption by, and adherence to, the coolers. Besides, the injury to the worts by long exposure to the atmospheric air within the fermentable temperatures is avoided.

The straight form and perpendicular position of the tubes afford peculiar facilities for cleansing them; a stream of water run into the cistern immediately after use, acquires such a force in passing through the tubes as to cleanse them effectually; and, if required, they may be scoured out with a rod and sponge, as gun-barrels are.

As the water used for refrigerating will never exceed the quantity required for the ordinary use of the brewery, it may be forced through the refrigerator on its passage from the well to the liquor back;—thus the refrigeration will be effected without any additional pumping. In case of a tube becoming defective, it may be easily removed, and replaced by another.

It is evident that the refrigeration may commence at any temperature below the boiling point, and extend to within a few degrees of the temperature of the cold water; but it is advisable to commence at about 100°, because, even when thickly spread, wort cools very rapidly at high temperatures in open vessels, and because a greater length of wort may be turned out of the copper, and therefore a greater extract obtained from the goods than when the great evaporation which takes place under such circumstances is prevented. The wort receives no injury from exposure to the air on the cooler while above the fermentable point, about 80°.

An example of the power of the refrigerator, as deduced from actual experiment, is as follows:—Assuming the cases to be 12 feet long, and to contain 169 tubes, of $\frac{1}{2}$ an inch bore in each; the temperature of the water to be 55°, (that of springs in general)—the wort to be cooled to 62°—and the quantities of cold water and wort, to be equal.

—	COMMENCING AT	
	100°	80°
No. 2 cools at the rate of	14 barrels per hour.	21 barrels per hour.
Nos. 1 and 3 " "	21 " "	30 " "

The rate of cooling varies in the compound ratios of the length and number of the tubes; and with respect to the above rates of cooling, if the refrigeration commence at a lower, or cease at a higher temperature, or if a larger proportion of cold water be used, or if the temperature of the water be lower, then those rates of cooling will be considerably increased.

No. 2 is a useful refrigerator for a small brewery, where the parties are not willing to incur the expense of guarding against the possible interruption caused by accident or repairs. No. 3 principally is recommended where there is a large quantity of wort to be cooled; for, instead of immoderately increasing the length or number of tubes in a case, it is more expedient to use two or more refrigerators of this construction. Thus, should it be desired to cool 100 to 150 barrels per hour, it may be done by connecting five of these refrigerators of the dimensions beforementioned; the whole would not occupy a ground plot of more than 10 feet by 3 feet, and if one of the set should require repair, it may be thrown out of use by merely turning a cock in each of the feeding pipes for water and wort, and a very available refrigator will still remain; and consequently the usual area of the coolers may be safely reduced as before suggested.

No. 1 is recommended where a cooling power of from 15 to 30 barrels per hour is desired, and where a present extra outlay is considered as compensated by a permanent benefit;—for as No. 1 possesses all the power of No. 3, with the capability of being used in other modes more advantageously under peculiar circumstances, and as, by merely turning certain cocks to proper positions, either part may be used alone, there remains, as in the preceding instance, a very available refrigerator, and the reduction of the coolers may safely be made.

HIGH PRESSURE BLOWING-ENGINE.

MADE BY MESSRS. MURDOCH, AITKEN, AND COMPANY, GLASGOW.

(Illustrated by Plates I. *and* II.)

FIG. 1, plate I, is a side elevation of the engine at half stroke, the near half of the entablature being supposed to be removed to show the work behind it. Figs. 2 and 3, plate II, are vertical sections of the steam-cylinder and the blowing cylinder respectively and figs. 4 and 5 are horizontal sections of the cylinders, at the plane A A, figs. 2 and 3. Fig. 6 is a plan of the main beam, and fig. 7 is a cross section at the plane A A, fig. 6.

The entablature, A A, besides being fixed into the walls of the engine-house, which are omitted in the plate for want of room, is supported at the centre upon two columns, B, placed exactly below the pedestals which sustain the main centre of the beam. The cylinders, C, D, are fixed one under each end of the beam E, equi-distant from the centre, from which it is obvious that the pistons of both cylinders have the same length of stroke, which is 8 feet. A fly-wheel F is introduced for the important purposes of equalising the motion of the engine and regulating the length of stroke, thereby superseding the necessity of spring beams for the latter purpose. The fly is driven by a crank, G, on the end of its shaft, which receives its motion from a connecting-rod H, hung from the beam at the most convenient intermediate position. In this case the length of crank is not, as in ordinary engines, equal to the half-length of stroke; but is reduced in proportion as the centre of suspension of the rod H is brought nearer to the main centre. This is obviously necessary to produce the proper length of stroke. Thus the half length of the beam being 13 feet, the centre of the bearing for the connecting rod end is 8 feet $1\frac{3}{4}$ inches, or 8·146 feet from the main centre of beam, as marked on fig. 6. If, then, the end centre of the beam vibrate through a vertical height of 8 feet, the vibration of the connecting-rod centre will be less in the ratio of 13 to 8·146, or equal to $\frac{8{\cdot}146 \times 8}{13} = 5{\cdot}013$ feet. The half of this will be the proper length of crank to give 8 feet stroke at the end of the beam; that is 2·506 feet, or 2 feet $6\frac{1}{16}$ inches is the length of crank.

The *steam cylinder*, 36 inches diameter, of which figs. 2 and 4 are sections, is wrought with a double short-slide valve, *a a*, the two parts of which are fixed by nuts to an upright valve-rod, *b*, which is driven from below, as may be understood from the elevation, fig. 1. The mode of stuffing the valve-rod is shown in the section; it consists of a short pipe *c*, a little wider than the rod, bolted by a flange to the bottom of the steam-chest. Another pipe *d*, which slides upon the pipe *c*, is fixed upon a conical part of the rod, where it is screwed up by a nut. The upper end of *d* is cup-shaped to admit stuffing, which is held down by a cover. The rod is guided at the lower end by a bush, *e*, fig. 1. A wrought-iron strap embraces the exterior pipe, having upon it two snugs connected by links to the wyper-shaft lever, as seen in fig. 1; *f* is the eccentric rod, and *g* is a counter-weight hung behind to balance the valve gear; *h*, figs. 2 and 4, is the exhaust passage.

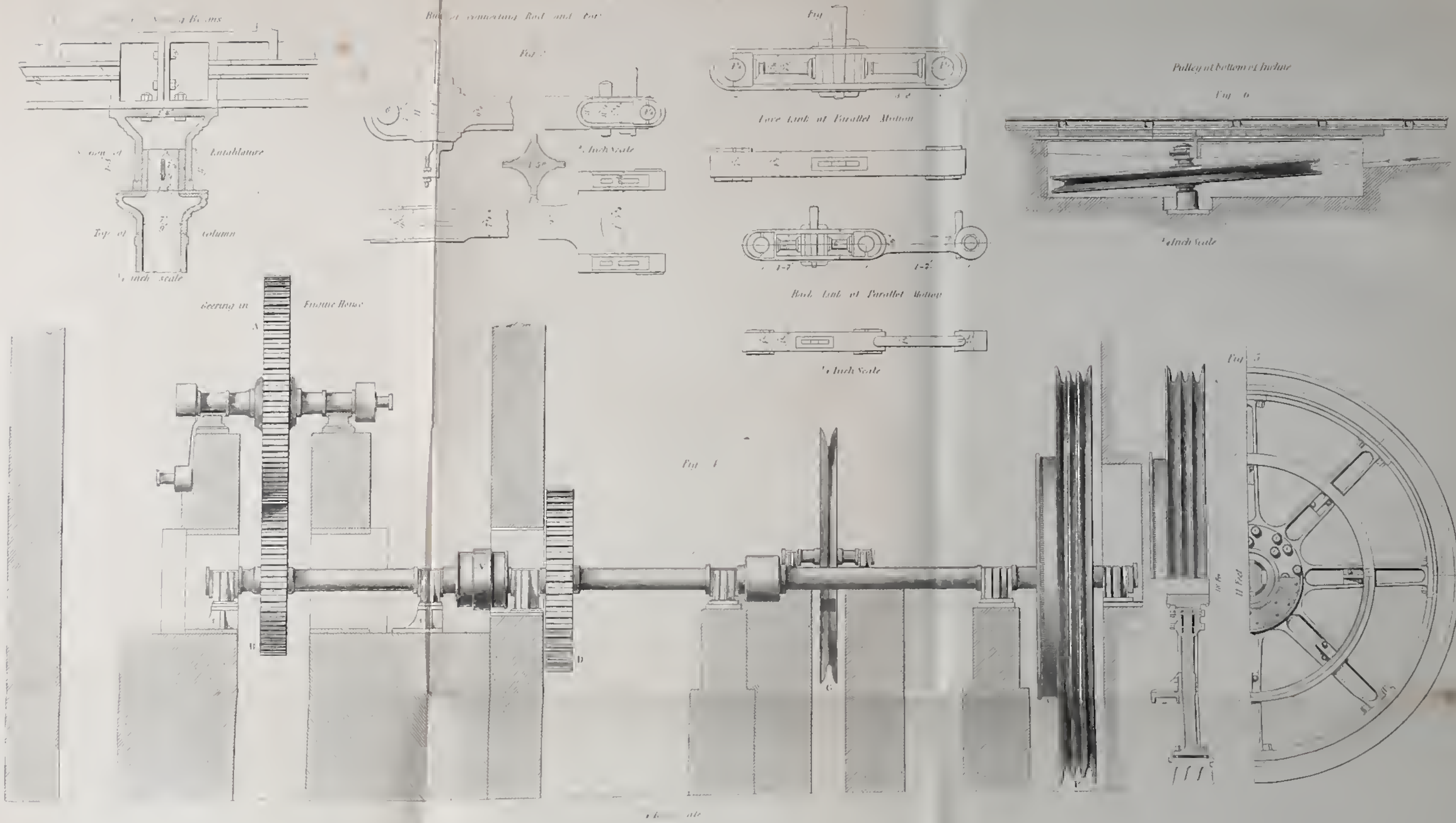
The *blowing cylinder*, of which figs. 3 and 5 are sections, is 90 inches in diameter. Its piston has the same depth as that of the steam-cylinder, and consists of a flat cast iron disc *i*, of nearly the diameter of the cylinder, being slack enough to work easily. A concentric double flange *k* goes round the piston, between the outside of which and the cylinder segments of wood are fitted, the office of which is to fix the leather-packing, and hold it against the cylinder. For this purpose, one edge of the leather is turned in below the segments and bolted to the disc by bolts and nuts *l*, and the other edge on the outside of the segments is held to the cylinder by set-screws *m*. Thus the double leather-packing prevents the escape of the air with comparatively little friction.

The cylinder is cast open at top and bottom, and is closed at the ends by the sole-plate *n*, to which it is bolted from below, and the cover *o*. Through these pieces the air enters from without, and for this purpose they are made with a series of apertures fitted with air-valves. The sole-plate is provided with seven apertures, as seen in the plan, one of them being shown fitted with its valve. The cover has six pairs of valves disposed in three small chests, cast on the upper side, of which one is shown in elevation, and one of them in section. The sides of the chests lie obliquely to the vertical, so that the valves may readily close the apertures when required.

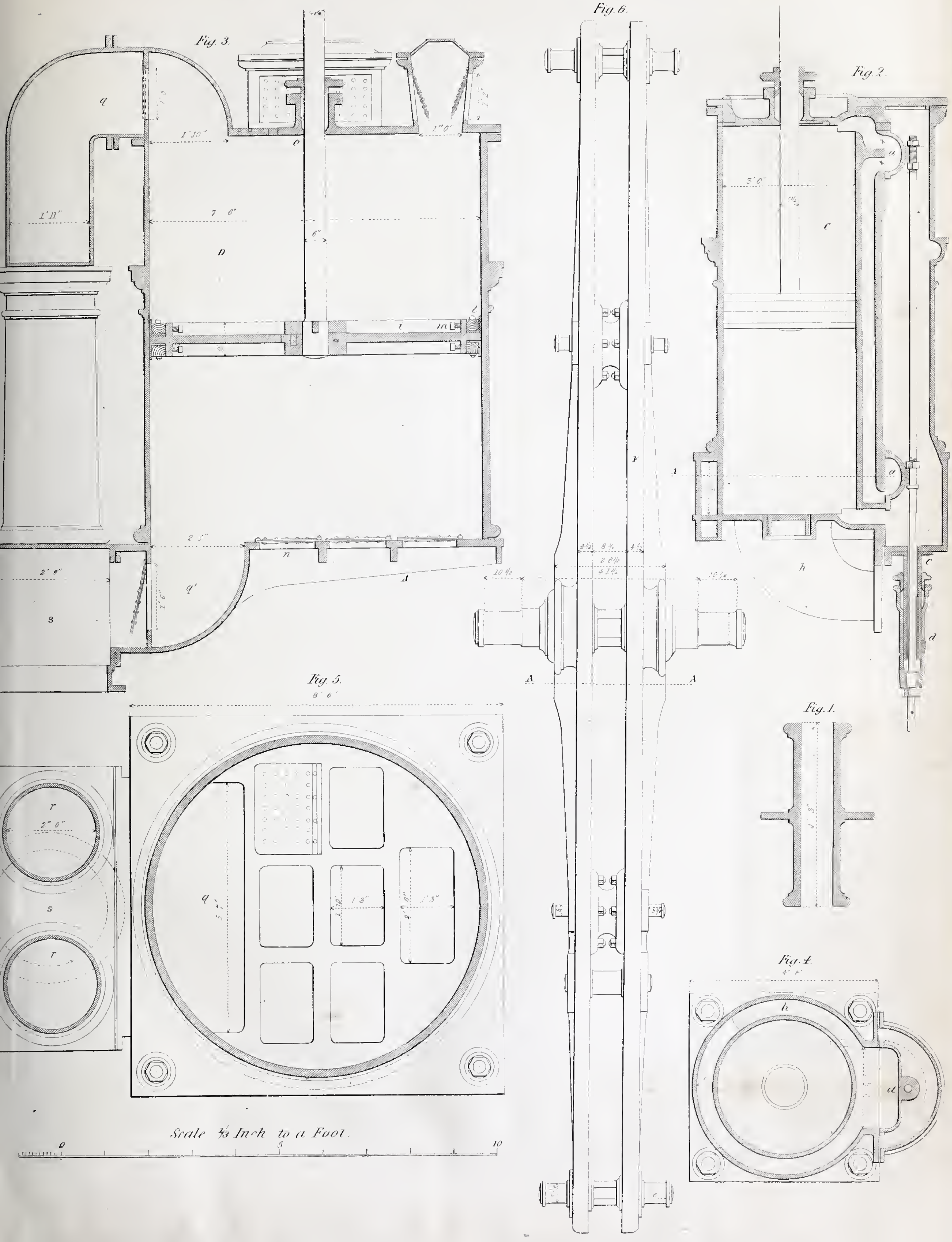
At one side of the cylinder, from the top and bottom, there proceed two large air-conduits, *q*, *q*'; the air in the upper conduit, *q*, descends in two currents through the columns, *r*, *r*, into the chest, *s*, where it meets the air from *q*'. From the under side of this chest the air is led off by a flanged circular opening to which an air conduit, *t*, fig. 1, of suitable diameter is bolted.

The air-piston is supposed to be descending, and the figure represents the corresponding positions of the air-valves, whether open or shut, occasioned by the action of the air.

DETAILS of ENGINES & GEERING.



DETAILS OF HIGH PRESSURE BLOWING ENGINE.



The *air-valves* are made of sheep-skin on which the wool is allowed to remain, the wool being useful for making the valves tight. Two plies of sheep-skin are laid together and fortified by iron plates on both sides, the whole being rivetted together by numerous small rivets, as shown in the drawing. In each valve the skin projects on one side, and is held down on the edge of the aperture by a strip of iron laid over it, which is screwed down by small pins. The natural bend of the skin thus furnishes a hinge upon which the valves are allowed to play, and it is of importance to the performanee of a blowing machine, that the passages through the valves should be sufficiently large to allow the air to pass very freely into and out of tho blowing cylinder, as fast as the piston can propel it.

GEOGRAPHY.

CHAPTER V

EUROPE—ITS BOUNDARIES AND DIVISIONS—ITS CLIMATE AND PRODUCTIONS—ITS INHABITANTS GOVERNMENT, AND RELIGION—ITS ISLANDS, MOUNTAINS, RIVERS, AND LAKES.

Europe is the smallest, but by far the best known and most important of the great divisions of land on the earth's surfaee. For more than twenty centuries it has been the great centre of art, literature, seience, and civilization; and although they sparkled for many ages with only a flickering and feeble light, thanks to the philosophers and sages who then preserved them amid surrounding darkness and devastation, they now burn with steady and effulgent splendour, and are shedding their benign influenees over the most benighted and distant portions of the globe.

Europe lies between the 36th and the 71st degrees of north latitude; and between the 10th degree of west, and the 64th degree of east longitude. Its greatest length, from its south-western to its north-eastern extremity, is 3490 miles; and its greatest breadth, from its south-eastern to its north-western extremity, is about 2400 miles. The superfieial area is about 3,822,000 square miles, and its population about 270,000,000.

BOUNDARIES OF EUROPE.—N. by Aretie Ocean.

W. by Atlantie Ocean.

S. by Mediterranean Sea, the Archipelago, the Sea of Marmora, the Blaek Sea, Sea of Azof, and the Caueasus Mountains.

E. by Asia, from which it is separated by the Caspian Sea, by the river Ural, and the Ural Mountains.

The most northerly point of the eontinent of Europe is Cape Nord Kun, in Finmark:—*Cape North* is on an island.

The most westerly point is Cape Finisterre, in Spain; or rather Cape Roca, or the Roek of Lisbon.

The most southerly point is Punta de Tarifa, in the strait of Gibraltar.

The most easterly point is perhaps at the mouth of the Kara river, where it falls into the Northern Ocean, separating European from Asiatic Russia.

GENERAL DIVISIONS OF EUROPE.—The *north* of Europe comprehends Lapland, Finland, the northern parts of Russia, Norway, Sweden, and Denmark.

The *north-east* of Europe is occupied by Russia, and the *south-east* by Turkey and Greece.

The *middle* regions of Europe eomprehend Austria, the German States, Switzerland; and, towards the west eoast, France, Belgium, Holland, Hanover, and Prussia.

The *south* of Europe eonsists of three great peninsulas, whieh eomprehend Spain and Portugal, Italy, Greece and Turkey in Europe.

On the *west* of Europe lie the British Islands: England, Scotland, and Ireland.

CLIMATE.—The *northern* countries of Europe lie, for the most part, north of the 55th degree of north latitude. Here the elimate is *cold* towards the north, and *temperate* towards the south.

The *middle* eountries of Europe lie between the 45th and the 55th degree of north latitude; in this region the elimate is *temperate* towards the north, and *warm* towards the south.

The *southern* countries of Europe lie to the south of the 45th degree of north latitude; and here the climate is *warm* towards the north, and *hot* towards the south.

The climate of Europe, except towards the northern extremity of the continent, is more agreeable and better adapted for the development of the physieal and intellectual faeulties of man, than any of the other divisions of the globe. It is little exposed to those extremes of heat and eold which are so eommon in most other regions; this may be attributed to the circumstance of its being surrounded on almost every side by seas, whose water is warmer than that of the ocean at large. The western coast of Europe, for example, is mueh warmer than the eastern coast of America under the same latitude; the differenee of temperature in some parts being equal to 10° of latitude.

In the *northern countries* of Europe, only two seasons oecur, summer and winter; the summer lasting about three months, and the winter nearly nine months. Spring and autumn can searcely be said to be known; they only comprehend a few days, and never more than two weeks. The vegetation is inconceivably rapid, and the heat of the summer very great. The winter is severe and boisterous, the ground being covered with an immense quantity of snow for a long period.

In the *middle countries* of Europe, the four seasons—spring, summer, autumn, and winter, are distinet; the one passing into the other by a very gradual transition. The extremes of heat and cold which are prevalent in the northern countries are here but little felt, the cold being much less severe in winter, and the heat less intense during the summer.

In the *southern countries* of Europe, frost and snow are of rare occurrence; vegetation is therefore but little interrupted during winter. They are subject, however, to great and eontinued droughts for four, five, and, in some places, occasionally eight or nine months during summer, and to abundant rains during the last three months of the year.

The following table is eompiled from the Temperature Tables communicated to the British Association for the advancement of Science, by Professor Dove of Berlin, in 1848; it gives the *mean* temperature of the principal towns of Europe for *each* of the *four seasons*, as well as for the *whole year*:—

Towns and Countries.	Feet above sea level	Mean Temperature.				
		Winter.	Spring.	Summer.	Autumn.	Year.
Torneo, (*Lapland*,)	...	6·41°	27·83°	57·89°	32·10°	31·06°
Kazan, (*Russia*,)	150	6·34	36·20	62·39	36·91	35·45
Umea, (*Lapland*,)	...	13·47	33·16	57·42	37·45	35·37
Petersburg, (*Russia*,)	...	18·66	37·06	61·68	41·02	39·61
Moscow, (*Russia*,)	400	15·20	40·98	63·97	39·94	40·02
Christiana, (*Norway*,)	74	23·18	40·08	59·88	42·62	41·45
Stoekholm, (*Sweden*,)	128	26·04	38·21	60·43	44·41	42·27
Warsaw, (*Russia*,)	351	24·91	43·05	63·21	45·41	44·15
Leipzig, (*Germany*,)	...	31·79	45·72	60·25	47·86	46·41
Copenhagen, (*Denmark*,)	...	31·31	43·54	62·70	48·70	46·56
Breslau, (*Prussia*,)	373	29·19	45·73	63·61	48·42	46·74
Dantzig, (*Prussia*,)	...	30·01	43·57	61·92	47·06	45·64
Edinburgh, (*Scotland*,)	220	38·45	45·02	57·17	47·89	47·13
Meiningen, (*Germany*,)	...	32·61	46·58	63·46	48·90	47·89
Bremen, (*Germany*,)	...	33·10	47·11	63·30	48·99	48·13
Berlin, (*Prussia*,)	160	31·45	47·41	64·56	49·23	48·16
Dublin, (*Ireland*,)	...	39·83	47·16	59·57	49·63	49·05
Plymouth, (*England*,)	...	44·88	49·68	60·87	52·91	52·08
Geneva, (*Switzerland*,)	1253	34·04	52·21	70·36	54·25	52·71
Vienna, (*Austria*,)	450	31·95	51·60	69·40	51·16	51·03
Brussels, (*Belgium*,)	262	38·01	49·04	64·04	51·60	50·68
London, (*England*,)	...	39·50	49·06	62·93	51·83	50·83
Paris, (*France*,)	114	37·85	50·62	64·58	52·20	51·31
Bristol, (*England*,)	...	40·33	50·33	64·33	51·67	51·67
Turin, (*Italy*,)	857	33·46	53·73	71·51	53·80	53·13
Nantes, (*France*,)	...	40·63	54·65	68·68	55·63	54·90
Trieste, (*Austria*,)	...	39·44	53·69	71·39	56·69	55·30
Bordeaux, (*France*,)	...	43·10	56·08	71·08	57·88	57·03
Madrid, (*Spain*,)	1939	43·16	55·64	76·40	57·44	58·16
Marseilles, (*France*,)	140	45·22	55·91	72·93	59·21	58·32
Rome, (*Italy*,)	160	46·73	58·25	74·24	62·75	60·49
Naples, (*Italy*,)	...	47·65	57·56	74·38	61·46	60·26
Genoa, (*Italy*,)	...	47·33	58·81	75·08	62·97	61·05
Lisbon, (*Portugal*,)	...	52·52	59·66	70·94	62·48	61·40
Messina, (*Sicily*,)	...	54·97	61·48	77·14	69·21	65·70
Barcelona, (*Spain*,)	204	50·18	60·37	77·0	64·51	63·03
Funchal, (*Madeira*,)	80	63·50	64·46	71·60	70·88	67·61
Cadiz, (*Spain*,)	...	52·90	59·53	70·43	65·35	62·06
Ionian Islands, (*Greece*,)	...	58·06	60·37	76·89	69·01	63·03
Malta, (*Mediterranean*,)	...	58·06	60·37	77·0	69·04	63·03
Gibraltar, (*Spain*,)	...	57·93	66·25	77·82	67·76	67·44

PRODUCTIONS.—The following table gives a general view of the chief productions and exports of the different countries of Europe:—

Countries.	Productions and Exports.
Great Britain,	Cottons, woollens, linens, hardware, salt, coals, iron, steel, earthenware, glass, machinery, fire-arms.
France,	Wines, brandy, silk (raw and manufactured), gloves, madder, fruits.
Spain and Portugal,	Olive oil, wines, raisins and other dried fruits, lemons, oranges.
Belgium and Holland,	Fine linen, lace, butter, cheese, corn, madder, geneva, flax, seeds, toys.
Germany,	Wool, corn, wines, linens, clover and rape seeds, wooden clocks.
Denmark,	Corn, rape-seed, fish, hogs.
Norway,	Timber, turpentine, fish.
Sweden,	Timber, iron, bark.
Russia,	Tallow, corn, flax, hemp, flaxseed, ashes, timber, tar, furs, quill feathers.
Prussia,	Corn, timber, flax, bark.
Austria,	Gold, silver, copper, iron, lead, salt, quicksilver, wine.
Switzerland,	Chamois skins, linen, watches, iron.
Italy,	Thrown silk, olive oil, currants, lemons, oranges, wine, barilla, shumac, cheese, straw-hats.
Turkey and Greece,	Figs, raisins, currants, raw silk, oil.

ANIMALS.—From its more temperate and colder climate, and from the extent to which the surface of the different nations has been brought under the dominion of man, Europe contains far fewer *wild animals* than any of the other great divisions of the globe. Those formidable enemies of the human species, the *bear*, the *wolf*, and the *wild boar*, once common in Britain and many other nations, have been in a great measure extirpated,—the white bear being confined to the polar regions, the brown bear, the wolf, and the wild boar, to the high mountains and wooded regions of Europe.

The *elk* and *rein-deer* are only found in the extreme north; while the *red-deer* and *roebuck* exist in some of the central countries.

The *chamois* or *wild goat*, and the *ibex*, are found in the Alpine regions of the south.

The other wild animals are the *lynx*, a feline animal, mostly confined to the south of Europe; the *fox*, in different varieties, distributed generally over the whole continent; the *common glutton* or *wolverine*, a native of Denmark; twenty-seven species of *bats*; the *beaver*, the *porcupine*, the *flying squirrel*, the *hamster*, and the *marmot*, are sparingly found in Europe; but *rats* and *mice* are very common. The *ibex* and the *musmon* are two quadrupeds, which are nearly extinct; the first supposed to be the original goat, the second the animal from which the sheep originated. The only quadrumanous animal is the *Barbary ape*.

The whole number of wild mammalia at present met with in Europe is only about 150, which includes 28 belonging to the whale, and 8 to the seal tribe. The number of land animals is thus reduced to 114, a very insignificant number compared with those found in the other great continents. Even of this small number, only 44 are now peculiar to Europe, the other 70 are found out of it, most of them being common to Asia.

The domestic animals, the *horse*, *ass*, *mule*, *ox*, *sheep*, *goat*, *dog*, *cat*, &c., are too well known to require more than a bare enumeration. We have, however, omitted to mention, in our remarks on the wild animals, the *wild cat*, a ferocious feline animal, which is still common in many parts of Europe.

BIRDS.—The birds of Europe are far more numerous than the mammalia. Upwards of 400 species are set down by naturalists as regular inhabitants of this continent, besides a number of occasional visitants.

In the northern regions, where animal life of every kind is but sparingly seen, the species of birds are comparatively few; and most of these belong to the swimming and wading orders, which in some places exist in immense numbers, and to whose subsistence and increase the arctic regions are peculiarly congenial.

As we proceed southward to a warmer climate and a more luxurious vegetation, more abundant food exists for the support of the feathered tribes, and accordingly we find the species of birds living on insects and the produce of the earth, to increase very much in number and variety.

The birds of Europe want that splendour and brilliancy of plumage, which is a remarkable peculiarity of the birds of tropical climates; but in many instances this deficiency is more than counterbalanced by the sweetness of their song. The nightingale, the most melodious bird in the world, is common in England and many parts of the continent, though not exclusively confined to Europe.

As we approach the southern limit of the continent, we would expect to find the characters of the birds assimilated to those of Africa and Asia; and such is actually the case: on the shores of the Mediterranean there is a union of the ornithology of Europe, Asia, and Africa.

REPTILES.—There are but few reptiles in Europe, and of those few, the greater part are harmless. The common *viper* is almost the only example of a venomous serpent. There are many small lizards, one species of turtle, and the strange amphibious reptile, called the *Proteus anguinus*.

INSECTS.—There are an immense number of *annulose* or articulate animals in this continent; among the more troublesome varieties, we have the *scorpion* in Sicily, and the *gnat* and the *mosquito* in Sweden during the summer months.

FISH.—Many of the *fish* which frequent the shores of Europe are very important in a commercial and economic point of view. Their capture and preparation employ a great number of men, and they occupy a prominent place as articles of diet. The *whale*, the *walrus*, *seal*, &c., inhabit the northern seas; the *anchovy* and *tunny* abound in the Mediterranean; and the *salmon*, *cod*, *ling*, *herring*, *haddock*, are plentiful in almost all the seas of Europe.

BOTANY OF EUROPE.—If we divide the space included between the equator and north pole into seven botanical regions, according to the mean annual temperature, it will be found that the first or *equatorial* region is the region of the *spices*; the second, the region of the *sugar-cane* and *coffee-tree*; the third, the region of the *fig* and the *olive*; the fourth, the region of the *wine-grape*; the fifth, the region of the *oak* and *wheat*; the sixth, the region of the *fir*, *pine*, and *birch*; and the seventh, the region of the *alpine shrubs*, *lichens*, and *mosses*.

It must, however, be remembered, that these regions are not exclusively occupied by the vegetable productions we have enumerated; nor are these productions confined to the particular regions; every plant requires a soil and climate suited to its nature, to enable it to arrive at perfection; and wherever these are found, whether in the regions specified or not, there will we find the characteristic vegetation arriving at the greatest maturity.

In accordance with these general views, we find the *warm* regions in the south of Europe occupied by the *fig*, the *olive*, the *orange*, *maize*, *Guinea corn*, the *sugar-cane*, *rice*, the *American aloe*, the *castor-oil* plant, the *vine*, the *date*, the *pisang*, and the *prickly pear*.

At about the 43d parallel of north latitude, which corresponds to the south of France, a marked change occurs in the vegetation; the tropical forms of plants disappear or become uncommon: still more to the north, the vine gives place to broad plains of wheat and other species of corn, and there we enter the fifth zone of vegetation—that of the *oak* and the *wheat*. Besides the oak, we have an abundance of *elms*, *limes*, *ashes*, *alders*, *beeches*, *birches*, *willows*, and *poplars*, with a richness of grass and herbage, quite unknown in the land of *olives*, *figs*, and *myrtles*.

The next region is that of the *fir*, the *pine*, and the *birch*; and it produces also the principal portion of food of the inhabitants—*oats*, *barley*, *rye*, and a few potatoes. The fruits are apples, pears, nuts, gooseberries, strawberries, &c.

In the frozen and polar region, we have but a very sparing vegetation, consisting chiefly of *alpine shrubs*, *lichens*, and *mosses*. From these parts of the world, however, we obtain valuable *animal* productions, as *whalebone*, *train oil*, and the *furs* of commerce.

MINERALS.—An amount of *gold*—at one time thought considerable—*silver*, *platina*, and *precious stones*, is found in various countries of Europe. Russia supplies the greater part of the *gold*, the *platina*, and *precious stones*, the remainder being furnished by Austria, Transylvania, and Saxony. *Silver* is

also produced in small quantities in Hanover, Turkey, Prussia, England, France, &c.

But although Europe cannot vie with other regions in its produce of the precious metals, she produces in abundance minerals far more useful to man, and much more productive of wealth than gold, silver, and precious stones. Her *iron, lead, copper, tin, quicksilver, coal, salt*, &c., have done more for the advance of civilization than all the precious metals of the world put together.

Iron.—Of the whole quantity of iron produced in Europe,

England furnishes	one-third.
Russia "	one-fourth.
France "	one-fifth.
Sweden "	one-tenth.

The Swedish and Russian iron is very superior, and well adapted for the fabrication of *steel;* for most purposes, however, the best English iron is nearly equal in value to the finest Swedish.

Lead.—

Spain supplies nearly	one-half.
England	three-sevenths.

Tin.—Nearly the whole of the *tin* produced in Europe is supplied by England, and more than one-half of the *copper;* while Russia supplies a fifth, and Sweden and Norway a tenth.

Coal.—England yields *ten* times as much coal as France, and nearly *seven* times as much as Belgium or Prussia.

Quicksilver.—Except a small quantity which is supplied by Spain and Bavaria, the mines of Idria, in the Austrian empire, yield almost the sole supply of quicksilver.

Platina.—This metal has been lately discovered in the Ural and Caucasian Mountains. *Zinc, cobalt, arsenic*, and nearly all the other known minerals, are found in Europe.

Statuary Marble of the finest quality is procured in abundance in northern Italy; while southern Italy and Sicily yield immense quantities of *sulphur, vitriol, sal-ammoniac*, and other valuable productions.

Salt.—The salt mines of Wielitzka, near Cracow in Poland, have a world-wide celebrity; but this useful condiment is found in almost every country of Europe.

Nitre is found in great quantities in Hungary.

Races of Men.—Man has been divided by Ethnologists into *four races*, or types:—The Caucasian, Mongolian, Ethiopian, and Malay races. And if we estimate the whole human race at nine hundred millions, we may roughly estimate the *Caucasian* to amount to three hundred and fifty millions; the *Mongolian* to four hundred and twenty millions; the *Ethiopian* to one hundred millions; and the *Malay* to thirty millions.

Nearly the whole of the inhabitants of Europe belong to the Caucasian variety; but along the borders of Asia, and towards the northern extremity of the continent, a few nations occur which belong to the Mongolian type; to these must be added the Magyars, who inhabit Hungary, in the centre of Europe.

If we adopt the division of the Caucasian race which is based on the peculiarity of their language, we will divide the inhabitants of that race into three great branches and several smaller ones. The *first* great division comprehends those languages which are in a great degree derived from the Latin, —the Italian, Spanish, Portugese, and French. The *second* comprehends those of Teutonic origin, and is spoken by the English, the greater part of the Scottish and Irish, by the inhabitants of Iceland, Norway, Sweden, Denmark, Germany, and the Netherlands. The *third* great branch is the Slavonian, which is spoken in various dialects in Bohemia, Silesia, Poland, Russia, Dalmatia, Croatia, Bosina, Servia, and Bulgaria. Besides these three great branches, dialects of the ancient Celtic language are spoken in Scotland, Ireland, Isle of Man, Wales, and Brittany.

Those inhabitants of Europe which belong to the Mongolian race, comprise—the Magyars, who inhabit the greater part of Hungary; the Lapps, the Finns, and the Samoyeds, who live near the arctic circle; the Inghers, the Esthonians, the Livonians, the Peruvians, the Wogules, and the Wotyakes, who all occupy different parts of the Russian empire. A few Calmucks, Khirghises, and Baskirs, inhabit the European side of the Ural Mountains. The Lithuanians and Courlanders speak languages peculiar to themselves. The south-east of Europe is inhabited by the Wallaches, the Turks, the Tartars, the Albanians, and the Greeks, who have all a distinct origin, and who speak peculiar languages.

The following is a table of the divisions and distribution of the Caucasian race over Europe:—

Celtic,	Spain, Portugal France. Switzerland (*part of*). Belgium (*mixed*). Britain (*mixed*).
Teutonic,	*Scandinavian.* Norway, Sweden. Denmark, Faroe. Iceland, Orkney. *German.* Germany, Holland. Switzerland (*part of*). Britain (*mixed*). Belgium (*mixed*).
Slavonic,	Russia. Poland, Lithuania. Bohemia, Moravia.
Mixed—Caucasian and Mongolian,	Finns, Lapps, Letts. Magyars. Turks. Basques. (?)

Religions of Europe.—The Roman Catholic religion prevails over almost all the nations in the south and middle of Europe; the Protestant religion over those in the north; and the Greek Church over those in the north-east. In some countries there is a mixture of Roman Catholics and Protestants, as in the German States, Belgium, &c. Mohammedanism is confined to Turkey and the extreme south of Russia.

The following table exhibits the numbers and nations professing the different religions, according to that excellent publication, the *Scientific Miscellany:*—

1. *Nations professing the Roman Catholic religion:*—
   Austrian empire, Bavaria, Belgium, France, Hungary, Ireland, Italy, Poland, Portugal, Spain. Part of Baden, Hesse-Cassel, and Hesse-Darmstadt, Holland, Prussia, the Rhenish provinces, Russia, Switzerland, and Wurtemberg,...... 154,444,600
2. *Nations professing the religion of the Greek church, which differs but slightly from the Roman Catholic:*—
   Greece, Russia, Moldavia, Wallachia, and part of Servia,... 60,000,000
3. *Nations professing the Protestant religion in various forms:*—
   Denmark, Norway, Sweden; greater part of England and Scotland; part of the northern and western states of Germany, of Holland, Prussia, and Switzerland,.................. 41,675,000
4. *The Mohammedan religion is professed by:*—
   Greater part of Turkey and small part of Russia,............... 6,178,400
5. *The Jewish religion is professed by:*—
   The descendants of the Hebrew race, thinly scattered over almost every nation in Europe; although they are most numerous in Russia, Poland, Austria, and Turkey,............. 1,752,000
6. *Armenianism is professed by:*—
   A few of the inhabitants of Russia, Austria, and Turkey,.... 200,000
7. *Bhuddism is professed by:*—
   The greater part of the Calmucks and Khirghises,............. 300,000
8. *Polytheism is supposed to be professed by:*—
   Some of the Laplanders and Samoyeds, and the Gipsies of the south-eastern countries of Europe,............................. 250,000

Political Constitution of Europe.—In Europe there are three forms of government:—

1. *Absolute monarchy* (of which there is no real example in Europe), is that form of government under which the legislative will of the sovereign is not subject to the control of any legally constituted or representative public body, such as a *parliament.*

2. *Limited* or *constitutional monarchy*, is that form of government by which the power of the sovereign is restricted by the laws, usages, and institutions of his country; and under which he is subject to the control of a representative public body.

3. *Republicanism*, is that form of government which is administered by rulers chosen from the people.

1. *The countries that have adopted limited, representative, or constitutional monarchies, are*—

Great Britain, Sweden, Norway, Holland, Belgium, Hanover, Bavaria, Baden, the two Hassias, Wurtemberg, Saxony, the Saxon Duchies, Mecklenburg, the smaller German States, and Greece.

2. *The countries under absolute monarchies are*—

Denmark, Russia, Turkey, and in a lesser degree France, Prussia, Austria, Italy, Sardinia, and some of the minor German States. In all these the despotism of Asia and Africa is unknown; the power of the sovereign is considerably restricted by the laws and institutions of the different kingdoms.

3. *The Republican form of government has been adopted only in the following places*:—

In the free and Hanse towns of Germany, viz., Hamburg, Lubeck, Bremen, and Frankfurt; in Switzerland; in the small states of the Ionian islands; in San Marino; and in Andorra.

Classification of the European States.—Great Britain, France, Russia, Austria, and Prussia, are called "the Five Great Powers of Europe." Spain, Sweden, and Turkey, are second-rate powers.

Holland, Belgium, Portugal, Naples, Bavaria, Sardinia, Denmark, Saxony, Wurtemberg, Hanover, and Switzerland, are third-rate powers; the remaining are fourth-rate, or less.

Liberty and Restriction of the "Press" in Europe.—*Repressive* measures of more or less rigour, either according to a particular system of laws upon the subject, or in consequence of the application of the common law on injuries, offences, &c., exist in Great Britain, Norway, Sweden, Holland, Belgium, Switzerland, Spain, Portugal, and Greece. *Preventive* measures by means of *Censorship* exist in Denmark, France, Germany, Russia, Italy, and Hungary.

Publicity of Judicial Proceedings and Trial by Jury, *exist in the following kingdoms and states*:—Great Britain, Belgium, France, Rhenish Prussia, Rhenish Hassia, Rhenish Bavaria, and Greece.

Some degree of publicity, but no Trial by Jury, exists in—

Several cantons of Switzerland, Norway, and Sweden.

Secret Tribunals and Legal proceedings exclusively written, not oral, exist in—

Denmark, Holland, Germany (except in the provinces above mentioned), Hungary, part of Switzerland, Spain, Portugal, Italy, Poland, and Russia.

Chief European Islands.—The following is a table of the principal islands of Europe, their situation, extent, population, and the countries to which they belong:—

	Belonging to	Position.	Area in Square Miles.	Population.
Great Britain,	Kingdom of	Atlantic Ocean.	90,311	20,936,468
Ireland,	Great Britain.	do.	32,512	6,515,794
Isle of Man,	do.	Irish Sea.	220	47,975
Channel Islands,	do.	Eng. Channel.	72	77,422
Malta,	do.	Mediterranean	100	118,759
Sicily,	Kingdom, pt. of	do.	10,500	2,040,610
Sardinia,	Kingdom, pt. of	do.	9,240	524,633
Corsica,	France.	do.	3,378	230,271
Elba,	Tuscany.	do.	Small.	13,500
Balearic Islands— Majorca, Minorca, Iviza, Formentera.	Spain.	do.	2,694	250,000
Ionian Islands,	Republic under prot. of G. Brit.	do.	Small group.	223,349
Candia,	Turkey.	do.	3,200	158,000
Azores,	Portugal.	Atlantic.	Group of 9 Is.	214,300
Zealand,	Denmark.	Baltic.	2,800	476,593
Funen,	do.	do.	1,470	158,282
Gothland,	Sweden.	do.	1,500	42,589
Hebrides,	Britain.	Atlan. Ocean.	Group of 200 Islands—80 inhabited.	108,146
Orkney Islands,	do.	do.	Gr. of 67 Is.	30,507
Shetland Islands,	do.	do.	Gr. of 100 Is.	30,558
Iceland,	Denmark.	N. Atl. Ocean.	40,000	57,094
Faroe Isles,	do.	do.	Gr. of 22 Is.	7,314
Spitzbergen,	Russia.	Arctic Ocean.	Group.	Uninhabit.
Nova Zembla,	Russia.	Arctic Ocean.	2 large Is.	Nearly uninhabitable.

The following table exhibits the *number of inhabitants to the square mile of surface*, in the different kingdoms and states of Europe:—

Name.	Population to sq mile.	Name.	Population to sq mile.
Lucca (Duchy),	400	Hesse-Cassel,	165
Belgium,	382	Sardinian States,	160
San Marino (Republic),	345	Papal States,	158
England,	298	Nassau,	154
Saxony,	296	Prussia,	150
Cracow,	269	Bavaria,	148
Ireland,	256	Austrian Empire,	144
Hesse-Darmstadt,	250	Swiss Confederation,	142
Holland,	239	Wales (England),	128
Wurtemberg,	220	Hanover,	117
Baden,	220	Mecklenburg-Schwerin,	102
Parma (Duchy),	213	Denmark,	98
Ionian Islands,	208	Portugal,	92
Modeno (Duchy),	200	Scotland,	87
Naples and Sicily,	194	Andorra (Republic),	75
Other German States,	190	Spain,	67
Tuscany (Grand Duchy),	186	Greece,	57
Saxe-Weimar,	177	Turkey (European),	45
Saxe-Coburg-Gotha,	176	Russian Empire,	26
Brunswick,	174	Sweden and Norway,	14
France (including Corsica),	173		

Mountains of Europe.—The following table gives a general outline of the principal mountains in Europe, their position, and the height of their culminating or most elevated points:—

Names of Mountain Ranges.	Culminating Points.	Heights in Feet.	Positions and Extent.
The Alps	Mont Blanc, Monte Rosa, Mont Cervin,	15,810 15,152 14,837	Highest and most extensive range in Europe. Separate France and Germany from Italy.
The Pyrenees	Pic de Nethou, Mont Perdu, Monteal,	11,426 10,994 10,663	Extend from Mediterranean to Bay of Biscay. They form a natural barrier between France and Spain.
Carpathian Mountains	Poyana—Rusca, Bukhest, Mont Tatra,	9,912 8,770 8,524	Extend in a curve from Presburg to Silesia. Between Galicia and Hungary, Transylvania and Wallachia.
Balkan System, or Mountains of Turkey and Greece	Sharra-tagh, Lactra, ancient Olympus, Liaktura, ancient Parnassus,	10,000 9,754 8,068	The principal chain in Turkey is the Balkan (ancient *Hæmus*); and in Greece the principal is the Pindus chain.
The Apennines	Monte Corno, Monte Sybilla, Monte Cimone,	9,523 7,212 6,975	This is the mountain system of Italy. It is an offset of the Alps, and traverses the whole peninsula.
Scandinavian Mountains	Snee-häetten, Skagstol-tind, Sylfiellen,	8,122 8,101 6,486	They separate Norway from Sweden, and take the names of Dovre-field, Lang-field, Soyne-field, and Hardanger-field.
Mountains of the Spanish Peninsula.	Peak of Mulhaçen, La Pena de Peneranda, Sierra de Gredos,	11,657 10,998 10,548	The principal ranges are—the Cantabrian range; the Castilian range; the Andalucian range; and the range of Granada.
Mount. of France	Puy de Saucy (top of M. Doré), Plomb du Cantal, Mont Mezin,	6,221 6,093 5,819	Form a large group in the south. Chief ranges—the Cevennes; the volcanic system of Auvergne; the Charolais; the Vosges; and the great plateau of Nether Rhine.
Mount. of Germany	Schnee-kopf, Schnee-berg, Rachelberg,	5,274 4,784 4,561	The principal groups are—the Fichtel-gebirge; the Erz-gebirge; the Böhmerwald; the Schwartzwald; and Odenwald; and the long range of the German Jura.
Mountains of Scotland—The Grampian Range	Ben Macdhui, Ben Nevis, Ben Lawers, Cairngorm, Ben Lomond,	4,390 4,370 3,945 4,095 3,190	The Grampian range is the most extensive in Britain. The other ranges are the Sidlaw Hills; the Ochils; the Pentlands; and the Cheviot Hills, which separate Scotland from England.
Mount. of England.	Snowdon, Helvellyn, Skiddaw, Scaw Fell,	3,571 3,055 3,022 3,166	England is not a mountainous country. The mountains of Wales, or the Cambrian system, are the highest.

Names of Mountain Ranges.	Culminating Points.	Heights in Feet.	Positions and Extent.
MOUNT. OF IRELAND.	Macgillieuddy's Reeks,	3,404	The principal range of mountains extends from E. to W. across the south-western part of Ireland.
	Lugnaquilla (Wicklow),	3,039	
	Slieve Donard,	2,796	
MOUNT. OF ICELAND.	Snaefell,	6,862	Volcanic eruptions are frequent in many parts of the island. 23 eruptions are recorded of Mt. Hecla. Last took place in April, 1766.
	Hecla (volcano),	5,210	
MOUNT. IN AZORES	Grand Pico,	8,057	
MOUNT. IN CORSICA	Monte Rotondo,	9,069	
MOUNT. IN SICILY	Etna (volcano),	10,874	In *Italian* Gibello. It is situated in the N.E. of the island.
MOUNT. IN CANDIA	Psiloritti (anc. Ida),	7,300	

PRINCIPAL EUROPEAN RIVERS.—Of the running waters of Europe the different seas are calculated to receive the following proportions, supposing the whole to be equal to 100:—

The Black Sea, ... 27 parts.
The Atlantic, including the German Ocean, ... 24 "
The Caspian Sea, ... 16 "
The Mediterranean, ... 14 "
The Baltic, ... 13 "
The Arctic Sea, about .... 3-5ths of part.

The following is a list of the principal rivers which fall into these seas, the direction in which they run, the countries through which they flow, their chief tributaries, and their lengths:—

1. *Rivers falling into the Black Sea.*

Name and Direction.	Countries they flow through.	Tributaries.	Length in Miles.
Danube,...S.E., E., N.E.	Germany, Hungary, Turkey	Ivon, March, Drave, Pruth, &c.	1,630
Dniepl,....S., S.E., S.W.	Russia	Pripel, Poug.	1,200
Don,............S., S.W.	Russia		1,100
Dneister, ...S.E.	Galicia, Russia		440

2. *Rivers falling into the Atlantic, including the German Ocean.*

Name and Direction.	Countries they flow through.	Tributaries.	Length in Miles.
Rhine, ...N., N.W.	Switzerland, Germany, Holland	Neckar, Maine, Moselle, Meuse.	760
Elbe, ...N.W.	Germany		690
Loire, ...N.W., W.	France	Cher, Indre, Vienne...	570
Tagus, ...W.	Spain, Portugal		510
Douro, ...W.	Spain, Portugal		460
Guadiana,..W., S.W., S.	Spain, Portugal		450
Seine, ...N.W.	France	Aube, Youne, Marne, Oise	430
Garonne............N.W.	France	Tarn, Sol, Dordogne...	350
Guadalquiver,......S.W.	Spain		290
Severn, ...S., S.W.	Wales, England	Terne, Avon, Wye	240
Shannon,...S., S.W., W.	West of Ireland	Suck	224
Thames, ...S.E., E.	East of England	Kennet, Lea, Medway.	215
Humber, ...E., S.E.	North-east of England.	Ouse, Trent	180
Mersey, ...N.W.	West of England	Irwell.	170
Barrow, ...S.	South of Ireland.	Nore	105
Clyde,...........W.N.W.	West of Scotland.		98
Spey, ...N.E.	North of Scotland	Avon	96
Tweed,...............N.E.	Between England and Scotland	Ettrick, Lauder, Till...	96
Tay, ...E., S.E.	Centre of Scotland	Tumel, Isla, Earn,	95
Dee,..............E. by N.	Scotland (Aberdeensh.)	Gairn, Feugh	87
Don, ...E. by S.	Scotland (Aberdeensh.)	Descry, Ury	65

3. *Rivers falling into the Caspian Sea.*

Name and Direction.	Countries they flow through.	Tributaries.	Length in Miles.
Volga, ...S.E., S., S E.	Russia	Mologa, Oka, Kama....	2,200
Ural or Jaik,...S.W., S.	Flows between Europe and Asia		550

4. *Rivers falling into the Mediterranean Sea.*

Name and Direction.	Countries they flow through.	Tributaries.	Length in Miles.
Rhone, ...S.	Switzerland, France...	Saone	490
Po, ...E.	Italy, and falls into Adriatic Sea	Ticino, Odda, Mincio...	450
Ebro, ...S.E.	Spain		420
Tiber, ...S.	Italy (Papal States)....		260

5. *Rivers falling into the Baltic Sea.*

Name and Direction.	Countries they flow through.	Tributaries.	Length in Miles.
Vistula,.........N.W., N.	Poland, Prussia		628
Dwina or Duna,.....S.W., N.W.	Russia		550
Oder.................N.W.	Germany		550
Niemen, N.W.,N.,N.W.	Russia, Prussia		500
Neva,....................W.	Russia		440
Weser, ...W.	Germany		280
Pregel, ...W.	Prussia		100

6. *Rivers falling into the Arctic Sea.*

Name and Direction.	Countries they flow through.	Tributaries.	Length in Miles.
Dwina,..........W., N.W.	Russia		760
Petchora,......N., W., N.	Russia		600
Mesen, ...W.	Russia		350

LAKES OF EUROPE.—The lakes of Europe are neither very numerous nor very important. There are numerous small sheets of fresh water which serve to vary, beautify, and enliven the scenery in the countries where they occur, but are of no importance in a commercial point of view; even the largest, which are the following, scarcely deserve the name of lakes, when compared to the vast inland seas of North America:—

In RUSSIA there are Lakes—Ladoga and Onega.
In SWEDEN there are Lakes—Wener and Wetter.
In SWITZERLAND there is Lake Geneva.
Between Switzerland and Germany there is Lake Constance.
In ENGLAND there are Lakes—Derwentwater, Ullswater, Windermere.
In SCOTLAND there are Lochs—Lomond, Awe, Tay, Leven, Ness.
In IRELAND there are the Lakes—of Killarney, Neagh, Erne, Allen.
IN ITALY there are the Lakes—Maggiore, Lugano, Como, Iseo.

FORMATION AND CHARACTERISTICS OF CORAL REEFS AND ISLANDS.

NATURE employs the most minute, as well as the most powerful and gigantic agents, in accomplishing her great operations on the face of the globe. The earthquake and the insect—the rush of the mighty river, and the movements of invisible molecules—are equally rendered subservient to bring about the mighty revolutions which have happened in successive ages, or cycles of time, and have left their imperishable records either on the lofty mountain range, or in the deep abysses of the ocean.

The coral insect is one of the most wonderful of Nature's minute agents. It is scarcely so large as a pin's head, and yet it erects the enormous reefs and beautiful coral islands which stud the Pacific, and most of the tropical seas—extending in vast numbers over the whole space comprehended between the 30th degree of latitude on each side the equator. The extent and magnitude of these reefs, may indeed be put in comparison with those of the older calcareous formations; they abound in the Indian Ocean, between Madagascar and the Malabar coast; in the Persian and Arabian Gulfs, to the latter of which it is conjectured that the name of the Red Sea has been given from its numerous coral formations; and

they are found also in the Mediterranean, off the Sicilian coast, and fringing the numerous islands of the Greek Archipelago. The great reef which follows the line of the north-east coast of New Holland is more than 1000 miles in length, with a thickness varying from less than twenty to more than a hundred feet; and there is one continued portion, exceeding 350 miles, of this prodigious submarine wall, without a single break to admit the passage of a vessel.

The general aspect of coral reefs, such as border most of the high islands of the Pacific, is that of a wide platform of rock, covered with the sea, except at low tide. In many instances the reef stands at a distance from the shores, like an artificial mole, leaving a wide and deep channel between it and the land; and often within the channel are other coral reefs, some in scattered patches, and others attached to the shore. In these cases the inner reef is distinguished as the *fringing* reef, and the outer as the *barrier* reef. "The sea," says Mr. Dana, "rolls in heavy surges against the outer margin of the *barrier*; but the still waters of a lake prevail within, affording safe navigation for the tottling canoe sometimes through the whole circuit of an island; and not unfrequently ships may pass, as by an internal canal, from harbour to harbour, around the island. The reef is covered by the sea at high tide, yet the smoother waters indicate its extent, and a line of breakers its outline. Occasionally, a green island rises from the reef; and in some instances a grove of palms stretches along the barrier for miles, where the action of the sea has raised the coral structure above the waves."

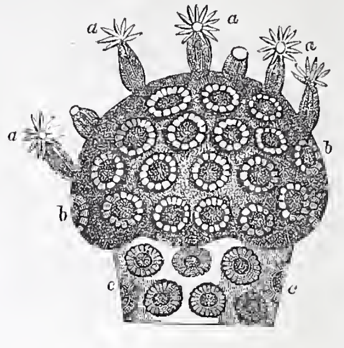
We annex, from the report of the Exploring Expedition, under Captain Wilkes, U.S.N., a sketch of the peculiar features presented by a Pacific island and its encircling reefs; but the writer of the report remarks, that "in order to fill out the scene, the jagged heights and deep gorges of the islands should be covered with forests, and the shores with groves and native villages."

Fig. 1.

Coral is almost entirely composed of pure limestone. The coral animalcule is regarded by Ehrenberg as a mere secreting membrane, having the power of separating limy or calcareous matter from the waters of the ocean, wherewith to fashion for itself an internal solid skeleton of carbonate of lime. The creature is star-shaped, is of a soft gelatinous structure, and myriads of them unite in their operations to form a single branch of coral. There are many species of the Coral zoophyte, each variety rearing its structure after a different form; and from this fact, such names have been given as tree coral, fan coral, organ-pipe coral, star coral, brain coral, &c.; or the synonymous scientific terms—caryophyllia, meandrina, astræa, porites, madrepora, tubipora, and such like. Fig. 2 exhibits a mass of astræa viridis: *a*, *a*, expanded polypes; *b*, *b*, polypes withdrawn into their cells; *c*, *c*, stony mass, uncovered by flesh.

The coral animalcules do not inhabit a very great depth; they generally commence their labours by attaching their structures to rocks from 60 to 100 feet below the surface, and thus the coral reefs partake of the shape of the submarine ridges on which they are founded. Indeed, though solitary branching corals have been dredged in fifty and even a hundred fathom water, the principal reef-builders are rarely found beyond the depth of forty, fifty, or sixty feet. It appears that the same law prevails as to the absence of organic existence in extreme depths of the ocean and at great heights in the atmosphere. It has been justly observed, with respect to this striking analogy, that "such an arrangement corresponds with all our ideas of vitality; corals, insects, and shell-fish can no more subsist under the pressure of extreme depth, absence of light and food, than plants can flourish in the thin cold atmosphere of highly-elevated regions."

Fig. 2.



Mass of Astræa viridis; *a*, *a*, expanded polypes; *b*, *b*, polypes withdrawn into their cells; *c*, *c*, stony mass uncovered by flesh.

The formation of coral reefs and islands is effected in the following manner:—The polypes, having attached themselves to the rocky bottom, generally the summit of some submarine ridge, proceed to build upward and around till the top of their structure just appears above low-water level. They then cease to build upwards, but still proceed seaward, increasing the breadth of the reef, and bringing each successive addition up to the surface. Shells and other sea-drift adhere to the structure in its progress, and gradually accumulate upon it, till the reef emerges from the ocean in the shape of a green island. The following account of the natural history of these wonderful structures, is given by an intelligent writer:—

"It seems to me," says Captain Flinders, "that when the coral animalcules cease to live, their structures adhere to each other by virtue either of the glutinous remains within, or of some propensity in the salt water; and the interstices being gradually filled up with sand and broken pieces of coral washed up by the sea, which also adhere, a mass of rock is at length formed. Future races of these animalcules erect their habitations upon the rising banks, and die in their turns, to increase, but principally to elevate, this monument of their wonderful labours. The care taken to work perpendicularly in the early stages, would mark a surprising instinct in these diminutive creatures. Their wall of coral, for the most part built in situations where the winds are constant, being arrived at the surface, affords a shelter, to leeward of which their infant colonies may be safely sent forth; and to this, their instinctive foresight, it seems to be owing that the windward side of a coral reef, exposed to the open sea, is generally, if not always, the highest part, rising almost perpendicularly, sometimes from the depth of two hundred, and perhaps many more, fathoms."

He adds—"To be constantly covered with water seems necessary to the existence of the animalcules, for they do not work, except in holes upon the reef, beyond low-water mark; but the coral sand, and other broken remnants thrown up by the sea, adhere to the rock, and form a solid mass with it, as high as the common tide reaches. That elevation surpassed, the future ones, being scarcely covered, lose their adhesive property, and, remaining in a loose state, form what is usually called a *key*, upon the top of the reef. The new bank is not long in being visited by sea-birds; salt plants take root upon it, and a soil begins to be formed; a cocoa-nut, or the berry of a pandanus, is thrown on shore; landbirds visit it, and deposit the seeds of plants, shrubs, and trees; every high tide, and still more every gale, adds something to the bank; the form of an island is gradually assumed; and, last of all, comes man to take possession."

Dr. Forster, who accompanied Captain Cook, remarks that

the curious process, which has just been described, is the most probable cause of the origin of all the tropical low isles over the whole South Sea. Indeed, an examination of their structure is sufficient to demonstrate this fact. Coral as produced by the zoophyte, is almost a pure carbonate of lime, soft and porous at first, but gradually becoming so hard and compact as to be used in the South Sea islands for building. Some sorts of coral are so hard as to take a fine polish, and are made into trinkets. The coral reef, however, is not a homogeneous mass—it encloses shells, fragments of drift-coral, sea-weeds, star-fishes, drift-wood, &c.; and these, being cemented in one mass by the growth of the new coral around them, and by other agencies, the rock presents a brecciated appearance, analogous to some older limestones.

Even the primitive homogeneous coral is, as we have previously stated, of different kinds; and, as an article sold in the market for ornamental purposes, its value depends upon the size, solidity, and colour of the specimen. The most highly prized varieties are the black and red, and portions of Sicilian coral have been known to bring so much as eight or ten guineas per ounce. But this is an extreme price; and other inferior portions of the same mass have sold for less than a shilling a pound. Abundant supplies of coral are obtained from the Red Sea, the Persian Gulf, the Eastern Archipelago &c., and regular coral fisheries have long been established in the Straits of Messina, on the shores of Majorca and Minorca, the coast of Provence, and in other parts of the Mediterranean.

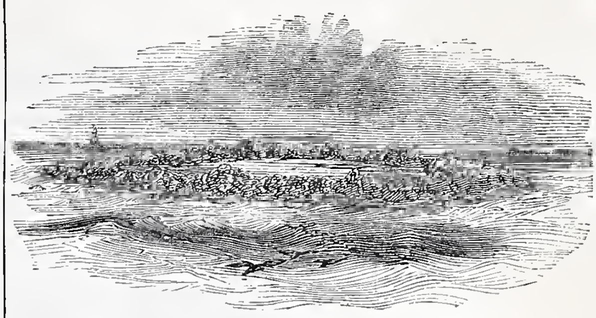
But, to return to the natural history of the coral formation, we may add to Captain Flinders' account, as given above, the following description, by Captain Basil Hall, of the coral polypes in active operation:—"When the tide," he remarks, "has left the rock for some time dry, it appears to be a compact mass, exceedingly hard and rugged; but as the tide rises and the waves begin to wash over it, the polypi protrude themselves from holes which were before invisible. These animals are of a great variety of shapes and sizes, and in such prodigious numbers, that in a short time the whole surface of the rock appears to be alive and in motion. The most common form is that of a star, with arms or tentacula, which are moved about with a rapid motion in all directions, probably to catch food. Others are so sluggish that they may be mistaken for pieces of the rock, and are generally of a dark colour. When the coral is broken about high water mark, it is solid hard stone; but if any part of it be detached at a spot where the tide reaches every day, it is found to be full of polypi of different lengths and colours; some being as fine as a thread, of a bright yellow and sometimes of a blue colour. The growth of coral appears to cease when the worm is no longer exposed to the washing of the sea. Thus, a reef rises in the form of a cauliflower till the top has gained the level of the highest tides; above which the animalcules have no power to advance, and the reef of course no longer extends upwards."

Captain Hall appears to be mistaken in stating that the reef ascends to the level of the highest tides. We have already remarked that the animal ceases to work beyond low-water mark, except when holes and crevices, by which the water is retained, are formed in the drift-accumulations at a higher level.

Our first sketch (fig. 1) exhibits a coral reef encircling a mountainous island. But reefs assume various forms; sometimes they are flat and oval or irregularly round, not intersected by channels; sometimes they shoot into long narrow islands, with cross channels at irregular intervals. One of the most common forms is the *circular* reef (fig. 3), consisting of a strip or belt of coral-made land, encircling a lake or lagoon instead of a high island. Of this latter kind are all the coral islands of the dangerous Archipelago: they consist of circular belts, from 400 yards to one mile across the ring; that is to say, across the strip or belt by which the lagoon is enclosed. The lagoons vary from two or three to 150 miles across; and the coral wall around them is generally intersected by deep channels, which allow a free communication between the lagoons and the ocean.

The different forms assumed by these reefs or islands depend on these of the submarine ridges or prominences on which they are reared. To account for the circular reefs, or *atolls*, it has been supposed that they are founded on submerged volcanoes, the edges of the crater forming a basis for the coral structure, and its interior hollow depth the lagoon. If this supposition

Fig. 3.



be correct, which is highly probable, the circular coral islands of the vast Archipelago are reared on the lofty summits of a submarine mountainous region, and each of them marks the position and form of what was an active volcano in former ages of the world.

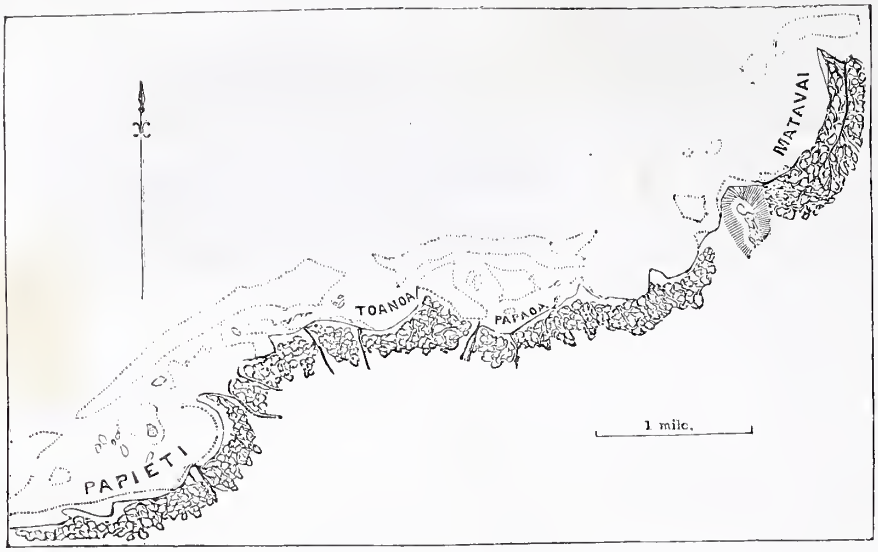
The coral-made land, when highest, is seldom elevated more than eight or ten feet above high tide. In some parts it is so low that the waves are still dashing over it into the lagoon. Mr. J. D. Dana, who accompanied the United States Exploring Expedition, thus describes the appearance of one of these circular coral islands:—"When first seen from the deck of a vessel, only a series of dark points is descried just above the horizon. Shortly after, the points enlarge into the plumed tops of cocoa-nut trees, and a line of green, interrupted at intervals, is traced along the water's surface. Approaching still nearer, the lake and its belt of verdure are spread out before the eye, and a scene of more interest can scarcely be imagined. The surf beating loud and heavy along the margin of the reef, presents a strange contrast to the prospect beyond—the white coral beach, the massy foliage of the grove, and the embosomed lake with its tiny islets. The colour of the lagoon water is often as blue as the ocean, although but fifteen or twenty fathoms deep; yet shades of green and yellow are intermingled, where patches of sand or coral-knolls are near the surface; and the green is a delicate apple-shade, quite unlike the usual muddy tint of shallow waters. The belt of verdure, though sometimes continuous around the lagoon is usually broken in some parts into islets which are separated by varying intervals of bare reef; and through one or more of these intervals, a ship-channel occasionally opens into the lagoon. The larger coral islands are thus a string of islands arranged along a line of coral reef. The king of the Maldives bears the high-sounding title of 'Ibrahim Sultan, King of the thirteen Atollons and Twelve Thousand Isles'; which Captain W.F.W. Owen, R.N., remarks is no exaggeration."

The annexed sketch (fig. 4) exhibits an outline of part of the north shore of Tahiti, from which an idea may be formed of the general grouping and appearance of coral islands and reefs. It presents a good illustration of the narrow channels which often occur, and at the same time exhibits the usual broken or interrupted character of reefs. The parts enclosed by dotted lines in this sketch are the fringing and barrier reefs. The outer reef extends half to two-thirds of a mile from the shore, and within it, between Papieti, and Matavai, there is an irregular ship channel, varying from three to twenty fathoms in depth. In some parts it enlarges into harbours, and in others it is very intricate, though navigable by large vessels throughout.

The water around coral islands deepens abruptly, and much in the same way as off the reefs about high islands, which may be regarded as submarine mountains, with their tops protruding above the ocean. Mr. Dana remarks that the atoll usually seems to stand as if stilted up in a fathomless sea, and he gives, from the soundings of the U. S. Expedition, some interesting

results. Seven miles east of Clermont Tenererre, the lead ran out to 1145 fathoms (6870 feet) without reaching bottom. Within three quarters of a mile of the southern point of this island, the lead, at another throw, after running out a while,

Fig. 4.



brought up an instant at 350 fathoms, and then dropped off again and descended to 600 fathoms without reaching bottom. From the various soundings it appears that, in general, for one to five yards from the margin of the shore reef, the water slowly deepens, and then there is an abrupt descent at an angle of forty or fifty degrees. It would seem also from the observations, that at considerable depths the sides of the coral structure may be vertical, or even may overhang the bottom below. It has been said that the reef to leeward is generally less abrupt than that to windward, but this is a point which later observations have not clearly established, although it appears that the difference, if any, must be slight.

Towards the lagoon side, the shore is generally low and gently inclined. In the larger islands, indeed, in which the waters of the lagoon are much disturbed by the winds, there

Fig. 5.

Fig. 6.

is usually a beach resembling that on the seaward side, though of less extent. The lagoons of the larger islands contain but small reefs compared with their whole extent; the greater part

Fig. 7.

Fig. 8.

is an open sea, with deep waters and a sandy bottom. Among the southern Maldives and others, there are instances of a depth of fifty and sixty fathoms. The bottom of these large lagoons is very nearly uniform, varying but little, except from the occasional abrupt shallowings, produced by growing patches of reef. Soundings bring up sand, pebbles, shells, and coral mud. In the smaller islands, the lagoons are usually very shallow, and in some merely a dry bed remains, indicating the former existence of water. The annexed cuts (figs. 5, 6, 7, 8,) exhibit four of the smaller coral islands. Taiara and Henuake (figs. 5 and 6) are two small belts of foliage, encircling their blue lagoons, and lying like garlands upon the waters. Henuake was found tenanted by birds, its only inhabitants; and they were so tame that the officers of the U. S. Expedition took them from the trees as if they had been their flowers. Swain's and Jarvis' Islands (figs. 7 and 8) are of still smaller size, and have no lagoon. The former is densely covered with foliage, while the surface of the latter is sandy. Though these two islets have no lagoons, the former was observed to be a little depressed about the centre, showing that a lagoon once existed.

In a great number of coral islands, the bank of reef has only here and there emerged from the waves, and become verdant. Of this we have an illustration in fig. 9, which is a sketch of Fakaafo or Bowditch, an island 200 miles north of Samoa. In the portions which

Fig. 9.

are not distinguished by verdure, the reef is of the usual height, or near the low tide level, except a few spots, shown in the figure, which have been a little elevated by the accumulation of sand.

To complete our account of these coral islands or atolls, we annex a section (fig. 10) of the general form of the rim or belt of land by which the lagoon is surrounded. In this section the breadth, *m n*, of the coral formation is shown, from the sea on the left to the lagoon on the right. The part, *m a*, represents the shallow sea, immediately bordering the island, and then deepening abruptly from one to six hundred feet at the line of breakers. From *a* to *b* is the shore platform of reef rock, nearly at low tide level. From this platform there is a rise by a steep beach, *b c*, of six or eight feet, to the wooded part of the coral

belt, extending from c to d. The beach of the lagoon slopes gently from d to e; from e to f the waters of the lagoon deepen gradually, and then the bottom descends more or less abruptly according to the depth of the enclosed lake.

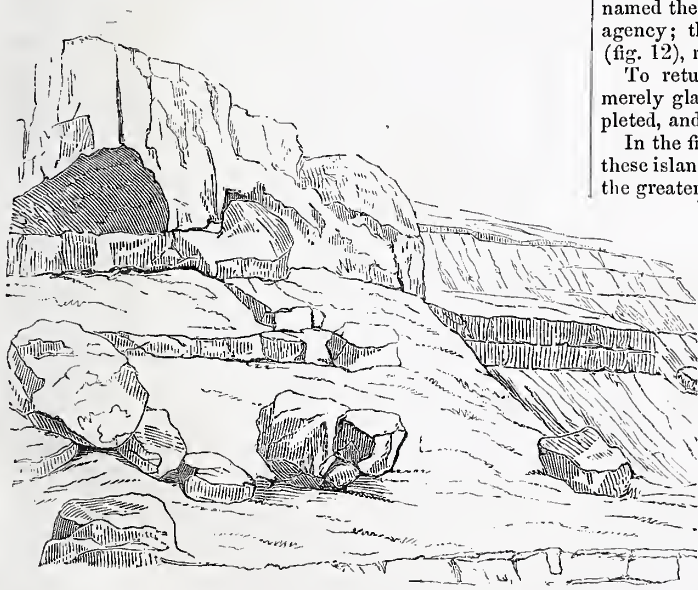
On the shore platform of these coral islands, huge masses of reef rock are often found. Some of these masses lie loose upon the reef, while others are firmly imbedded in it below. These remarkable masses are not found clustered together, but quite

Fig. 10.

isolated, and only at considerable intervals. They are usually a solid conglomerate, consisting of large fragments of Astræas and Madrepores, and containing some imbedded shells. One mass of this description was observed, quite unattached below, which contained at least a thousand cubic feet of conglomerate.

Another characteristic formation is the drift sand-rock, which occurs only on the windward side of islands when the reefs are narrow, and proceeds from drift sands. They resemble ordinary sand-drifts hardened into solid rock. This kind of beach formation is found in great perfection in Oahu, an island in the Hawaiian group, occurring at intervals along the eastern shores, the part exposed to the regular trade-winds. We annex a sketch (fig. 11) of the bluffs of this coral sand-rock observed on the north shore of the island. In some places they are twenty to thirty feet in height. Through the agency of infiltrating waters, fresh or salt, these sand banks became cemented into a sand rock, more or less friable. It consists of thin layers or laminæ, quite distinct,

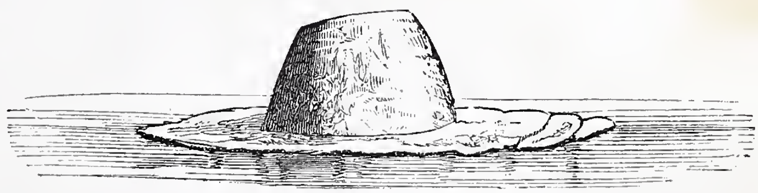
Fig. 11.



and indicating every successive drift of sand which puffs of wind had added in the course of its formation. At one of the hills, large slate-like slabs were obtained, having a sanded surface, but so hard within as to clink under the hammer. These drift sand-rocks are found only on high islands surrounded by coral reefs.

Another peculiarity of these islands is the *shore platform*, which, as we have stated, lies but little above low tide level, and is often three hundred feet in width, with a nearly flat surface throughout. The existence of this platform is not, indeed, a characteristic of the coral formation, but is due to the simple action of the sea, and is found abundantly exemplified on other rocky islands. New Zealand, for instance, at the Bay of Islands, exhibits this feature in a simple argillaceous sand rock.

Fig. 12.



At the base of the sandstone cliff, in most places one or more hundred feet in height, there is a layer of sandstone rock, lying like the shore platform of the coral islands, near low tide level, and from fifty to one hundred and fifty yards in width. The water, in these cases, has worn away the cliffs, leaving the basement untouched. A small island in the above bay is well named the "Old Hat" from the appearance produced by this agency; the platform encircling it, as shown in the sketch (fig. 12), resembles a broad brim to a rude conical crown.

To return, however, to the coral island or atoll, we shall merely glance, in conclusion, at some of its features when completed, and fit for the habitation of man.

In the first place, the small amount of habitable land upon these islands is one of their most peculiar features. In general the greater part of the surface is water; and the land around the lagoon is but a narrow ring, of which the most considerable portion is usually under water at high tide. For instance, the island of Carlshoff, Paumotus group, is 27 miles long by 13 of greatest breadth; the whole area in square miles is 200, of which the habitable portion is only 10 square miles. The area of Nairsa or Deans is 100 square miles; the habitable part only 16. Fakaafo, of which a sketch has been given, is 20 square miles in superficial extent, of which only $2\frac{1}{2}$ are habitable. There are ten of these islands which embrace an aggregate area of 1952 square miles, while the amount of actual dry habitable land is but seventy-six miles, or less than one twenty-fourth. In the Caroline Archipelago, the proportion of habitable land is still smaller, averaging not more than one per cent., while in the Pescadores the proportion of land to the whole area is about as 1 to 200.

"The coral island in its best condition," says Mr. Dana, "is but a miserable residence for man. There is poetry in every feature; but the natives find this a poor substitute for the breadfruit and yams of more favoured lands. The cocoa-nut and pandanus are, in general, the only products of the vegetable kingdom afforded for their sustenance, and fish and crabs from the reefs their only animal food. Scanty, too, is the supply; and infanticide is resorted to in self-defence, where but a

few years would otherwise overstock the half-a-dozen square miles of which their little world consists. Yet there are more comforts than might be expected on a land of so limited extent, without rivers, without hills, in the midst of salt water, with the most elevated point but ten feet above high tide, and no part more than 300 yards from the ocean. Though the soil is light, and the surface often strewed with blocks of coral, there is a dense covering of vegetation to shade the native villages from a tropical sun. The cocoa-nut, the tree of a thousand uses, grows luxuriantly on the coral-made land, after it has emerged from the ocean; and the scanty dresses of the natives, their drinking vessels and other utensils, mats, cordage, fishing-lines, and oil, besides food, drink, and building materials, are all supplied from it. The pandanus, or screw-pine, flourishes well, and is exactly fitted for such regions: as it enlarges and spreads its branches, one prop after another grows out from the trunk and plants itself in the ground; and by this means its base is widened and the growing tree supported. The fruit, a large ovoidal mass, made up of oblong dry seed, diverging from a centre, each near two cubic inches in size, affords a sweetish husky article of food, which, though little better than prepared corn-stalks, admits of being stored away for use when other things fail. The extensive reefs abound in fish, which are easily captured, and the natives with wooden hooks, often bring in larger kinds from the deep waters. From such resources a population of 10,000 persons is supported in the single island of Taputeouea, whose whole habitable area does not exceed six square miles. This island, indeed, is well supplied with vegetable food, although the above statements are literally true of a large majority."

Water is found by digging wells five to ten feet deep in any part of the dry islets. From these the natives obtain a constant and sufficient supply. The only source of this water is the rains, which, percolating through the loose surface, settle upon the hardened coral rock that forms the base of the island.

Some of the islands enclose ports of great extent, many admitting even the largest class of vessels. Their lagoons are the pearl fisheries of the Pacific. Notwithstanding the great number of coral islands in the Paumotus Archipelago, the botanist finds among the tropical luxuriance of their vegetation, only twenty-eight or twenty-nine native species of plants.

The coral islands are exposed to carthquakes and storms, like the continents, and sometimes a devastating wave sweeps across the land. The natives, during the heavier gales, secure their houses by tying them to the cocoa-nut trees, or to a stake planted for the purpose.

We conclude with the following remarks and judicious reflections by Mr. Dana on the moral and intellectual state of the inhabitants of these interesting islands:—

"The language of the natives indicates their poverty, as well as the limited productions and unvarying features of the land. All words like those for mountain, hill, river, and many of the implements of their ancestors, as well as the trees and other vegetation of the land from which they are derived, are lost to them; and as words are but signs for ideas, they have fallen off in general intelligence. It would be an interesting inquiry for the philosopher to what extent a race of men placed in such circumstances are capable of mental improvement. Perhaps the query might be best answered by another, how many of the various arts of civilized life could exist in a land, where shells are the only cutting instruments—the plants in all but twenty-nine in number—but a single mineral—quadrupeds none, with the exception of foreign mice—fresh water barely enough for household purposes—no streams, nor mountains, nor hills? How much of the poetry or literature of Europe would be intelligible to persons whose ideas had expanded only to the limits of a coral island—who had never conceived of a surface of land above half-a-mile in breadth—of a slope higher than a beach—of a change of seasons beyond a variation in the prevalence of rains? What elevation in morals should be expected upon a contracted islet, so readily overpeopled that threatened starvation drives to infanticide, and tends to cultivate the extremest selfishness? Assuredly there is not a more unfavourable spot for moral or intellectual development in the wide world than the coral island, with all its beauty of grove and lake."

The reader will agree that these observations, expressed with so much eloquence and force, are perfectly just. The beauty of the coral island is chiefly poetical, its value is chiefly geological; although it may be yet destined to serve important purposes in the world's progress.

THE ELECTROTYPE.

CHAPTER VIII.

DEPOSITING PALLADIUM AND PLATINUM—ELECTRO-PLATING AND GILDING—EFFECTS ON HEALTH.

In our last chapter we described the processes of coating iron with copper and zinc, of bronzing, and of operating generally with the baser metals. We now proceed to explain the methods of electrotyping with the finer metals, and especially the processes of plating and gilding, which, although briefly described in our second chapter (Vol. I. p. 273), are entitled, by their great importance in the arts, to a more detailed elucidation.

Palladium is a metal both easily and economically deposited; and were that metal to be had in sufficient quantity, it would make an excellent coating for lamp furniture and other objects; but, from its scarcity, palladium is too expensive for ordinary use, and it wants the beauty of silver and gold for superior purposes. To prepare the solution, the metal is dissolved in nitro-muriatic acid, which is then evaporated nearly to dryness, and cyanide of potassium is added till the whole is dissolved. The solution, being then filtered, is ready for use. The best application of this metal would be the protection of other metals from the action of acids; and for this purpose is required a tolerably thick deposit.

Platinum is rather difficult to be operated upon by the electric current. One great cause of the difficulty is the insoluble nature of the metal; and although there is a positive electrode used with the solution which gives a metallic deposit, it is hardly acted upon, so that the solution is instantly comparatively exhausted of metal; and as the battery power is regulated to the original strength, it becomes in a few seconds too powerful; hence the metal begins to be deposited as a black powder. These, and many other practical difficulties, are still in the way of an extensive application of this metal to general use by means of electric deposition. We have ourselves covered iron, copper, and brass with platinum, which have stood untarnished amid the fumes of a laboratory for eighteen months, but the obtaining of such samples was attended with much labour. The solution is made, as for palladium, by dissolving the metal in a mixture of nitric and muriatic acids; but it is necessary to apply heat. When evaporated to dryness, a solution of cyanide of potassium is added to the remaining mass; and after being slightly heated for a short time, it is then filtered. Even with the greatest care, the operator often fails in getting more than a mere colouring of metal over the surface, and that not very adhesive.

Without particularizing other metals, the most of which have been subjected to electro-deposition, we shall now describe in detail the method of depositing the two principal metals whose application has become so common—namely, silver and gold. The art of depositing these two metals for the purpose of coating other metals, known as *plating* and *gilding*, has become an established branch of British art; and we are persuaded, that in a few years the old modes of plating and gilding will be entirely superseded by the electro processes now in vogue.

ELECTRO-PLATING.

The method of plating commonly practised, is conducted by laying upon a clean block, or ingot of copper, an ingot of silver of equal surface, but less or more in weight according to the quality of the article wanted, with a flux of sal-ammoniac interposed between them. In this state they are put into an

appropriate furnace, and heated to such a temperature, that the two surfaces of the metals, by aid of the flux, become partially fused together. They are then rolled into a sheet, from which the goods are made up; and when the article to be made is composed of more pieces than one, these are cemented by means of what is termed soft solder, which is a mixture of lead and tin. Hard solder cannot be used for this purpose, as the silver is so thin that it would be either melted or blistered by the heat. When wrought work or ornaments are wanted, steel dies or moulds of the particular pattern are obtained, and a thin sheet of silver being laid upon these moulds, it is struck or pressed into them. Thus the silver receives the impression of the mould; these impressions are very appropriately termed shells, and being afterwards filled with soft solder, they are fixed upon the appropriate parts by means of the same substance. It is hardly necessary to observe, that articles made up in this way are wanting in solidity, as the nature of the plate does not allow it; but, by the electro process, the making of the article has nothing to do with the plating of it. The articles are all made previous to being plated, and therefore may be cast of any pattern in solid metal; or, if composed of parts, these parts may be put together by hard solder, or any kind of solder found necessary for the strength of the article.

In the process previously given for preparing the solution (Vol. I. p. 274), a solution of oxide of silver in cyanide of potassium was recommended. The method of preparing the cyanide was described in last chapter, and therefore, to complete our account of this process, it only remains to describe the most effective method of preparing the oxide of silver. For this purpose, equal parts of water and strong nitric acid are poured on pieces of silver placed in a glass vessel. When the metal is dissolved, which will rapidly take place, the solution is exposed in a saucer or evaporating dish to the heat of a spirit-lamp or clear fire, till part of the liquid is driven off in vapour. The solution is allowed to cool, when long colourless crystals of nitrate of silver will be formed. These, when fused and run into moulds, are the lunar caustic of surgery, and therefore must be handled with care, as they stain the fingers an almost indelible black. The crystals are dropped into a very considerable quantity of lime-water, and *oxide of silver* gradually subsides in the form of a dark-brown precipitate. This, when the liquid has been decanted off, is washed with water; and, instead of being dried, it should be kept in bottles with water. A quarter of an ounce of oxide of silver, added to a pint of the solution of cyanide of potassium, forms a very useful plating solution.

It ought to be observed, however, that this preparation is not the most economical, because the materials used in converting the silver into an oxide are lost. The following process for making the electro-plating solution is, therefore, recommended as preferable.

Metallic silver is dissolved in four parts of nitric acid diluted with one part of water; the diluted acid being heated in a vessel, and the silver added by degrees. The operator must avoid breathing the fumes which ascend, as they are highly deleterious. The metal being dissolved, the solution is transferred to a large vessel, and diluted with water. To this is added a solution of cyanide of potassium, so long as a white precipitate is formed. This precipitate is cyanide of silver, and the action which ensues may be thus represented:—

Nitrate of Silver	Silver 1		1 Cyanide of Silver.
	Nitric Acid 1		
Cyanide of Potassium	Cyanogen 1		
	Potassium 1		1 Nitrate of Potash.

To remove the nitrate of potash which remains in solution, the precipitate is well washed by filling up the vessel several times with water, allowing the precipitate to settle, and pouring off the clear fluid. Having been properly washed, a solution of cyanide of potassium is added until the whole precipitate is dissolved. This constitutes the cyanide of potassium and silver, and forms the plating solution, which ought to be filtered before being used.

The amateur electrotypist may make up a small quantity of solution for the purpose of silvering his medals or little figures, without going through the routine of dissolving the silver in acids, and he will have a much purer solution. One ounce of cyanide of potassium being dissolved in a quart of distilled water, a small porous vessel is filled with the cyanide solution, and placed into the vessel containing it. A piece of copper or any other metal is put into the porous vessel, and attached to the zinc terminal of a small battery. A piece of silver of any size is likewise put into the other vessel, and attached to the copper terminal: the current being thus excited, and allowed to pass through for 24 hours, the silver is dissolved by the current, and a pure solution of cyanide of potassium and silver is formed. The solution in the porous cell may be thrown away, as it contains all the potash which has been formed by the current from the decomposition of cyanide of potassium. The solution thus formed yields a most beautifully coloured deposit.

Articles that are to be plated, are first boiled in an alkaline ley, to free them of any grease; then washed from this, and dipped into dilute nitric acid, which removes any oxide that may be found upon the surface: they are afterwards brushed over with a hard brush and sand. The battery being connected to a plate of silver in the solution by the copper terminal, the zinc of the battery is attached to a wire or rod which lies across the mouth of the vessel holding the solution. The medal or article to be plated has a copper wire attached to it, either by twisting it round the article, or putting it through any open part of it, to maintain it in suspension. It is then dipped in nitric acid as quickly as possible, and washed through water, and then immersed in the silver solution, suspending it by the wire which crosses the mouth of the vessel from the zinc of the battery. The article is instantaneously coated with silver, and ought to be taken out after a few seconds, and well brushed. On a large scale, brushes of brass wire, attached to a lathe, are used for this purpose; but a hard hair-brush, with a little fine sand, will do for small work. This brushing is used in case any particle of foreign matter may be still on the surface. It is then replaced in the solution, and, in the course of a few hours, a coating of the thickness of tissue-paper is deposited on it, having the beautiful matted appearance of dead silver. If it is desired to preserve the surface in this condition, the object must be taken out, care being taken not to touch it by the hand, and immersed in boiling distilled water for a few minutes. On being withdrawn, sufficient heat has been imparted to the metal to dry it instantly. If it is a medal, it ought to be put in an air-tight frame immediately; or, if a figure, it may be placed under a glass shade, as a very few days' exposure to the air tarnishes it, by the formation of a sulphuret of silver, and that more especially in a room where there is fire or gas. If the article is not wanted *dead*, it is brushed with a wire-brush and old ale, but the amateur may use a hard brush and whiting. It may be afterwards burnished according to the usual method of burnishing, by rubbing the surface with considerable pressure with polished steel, or what is termed *bloodstone*, an oxide of iron. We may remark, that in depositing silver from the solution, a weak battery may be used; though, when the battery is weak, the silver deposited is soft, but if used as strong as the solution will allow, say 8 or 9 pairs, the silver will be equal in hardness to rolled or hammered silver. If the battery is stronger than the solution will stand, or the article very small compared to the size of the plate of silver forming the positive electrode, the silver will be deposited as a powder. Gas should never be seen escaping from either pole; the surface of the article should always correspond as nearly as possible with the surface of the positive electrode, otherwise the deposit is not good, and the solution is apt to be destroyed. The average cost of depositing silver in this way is 2d. per ounce.

Other solutions have been used—as the hypo-sulphite and sulphite of silver—but not with equal success; and therefore we think it would be inexpedient to distract the reader's attention, by giving the details of the processes for their preparation. We shall simply state, that the hypo-sulphite of silver is formed by dissolving the chloride of that metal in hypo-sulphite of soda. The sulphite or silver-plating solution, which is termed by the patentee of the process, "silvering liquor," is formed by dissolving crystallized nitrate of silver in

solution of sulphite of potash—the latter being formed by saturating a potash solution with sulphurous acid gas. Both the sulphite and hypo-sulphite of silver are liable to decomposition by light, and have not been found, in practice, so good as the solution of cyanide of potassium and silver for plating purposes.

It sometimes happens that a silver solution gets out of order, and cannot be again applied to a useful purpose. In that case, the silver may be thrown down by muriatic acid; but it is better to evaporate the solution to dryness, and to fuse the residue, by which means the silver is recovered in a metallic state. In "replating" articles, from which the previous coating of the metal has been partly worn off, it is found to be the best way, in many cases, to take all the old silver off the article, and give it an entirely new coating. There are two methods of removing the silver;—either by dissolving it off among strong sulphuric acid, to which a little nitrate of potash has been added; or by applying to the plated article a circular brush fixed upon a lathe, and a paste made of oil and pumice-stone, ground as fine as flour. The sulphuric acid, by liberating the nitric acid from the nitrate of potash, dissolves the silver without materially affecting the copper, if that be the metal which forms the basis of the article, and having diluted the sulphuric acid after it is saturated with silver, the latter is easily precipitated by a solution of common salt. The precipitate is chloride of silver; and this being collected and fused in a crucible along with carbonate of potash, yields the metallic silver back. The preferable mode, however, and that which is commonly adopted, is simply to brush off the silver by the method above described, and to fuse the brushings when collected and dried with carbonate of soda and potash.

Any thickness of silver may be given to a plate, according to the length of time that the operation is continued. An excellent plate, about the thickness of ordinary writing-paper, is afforded by $1\frac{1}{4}$ or $1\frac{1}{2}$ ounce of silver to the square foot of surface. It is a remarkable fact, that the ordinary chalky appearance which characterizes electro-plated articles before being scratch-brushed, may be prevented by adding to the plating solution a little sulphuret of carbon, which gives the deposit the same appearance as if the article were scratched —that of metallic silver

"Silver," says Mr. Napier, "may be deposited upon any metal, but not upon all with equal facility. Copper, brass, and German silver, are the best metals to plate; iron, zinc, tin, pewter, and Britannia metal, are much more difficult; lead is easier, but it is not a good metal, because of the rapidity with which it tarnishes, and from its softness easily yields to the pressure of the burnisher: nevertheless, all these metals and alloys may be and are plated, but cannot give the satisfaction which brass, copper, or German silver afford."

We cannot better conclude our account of the electro-plating process, than by giving, from the same author, the following arrangement, described as that adopted in some of the large plating manufactories:—"The *vat*, or plating vessel, measures about $6\frac{1}{2}$ feet in length, by 33 inches in breadth, and 33 inches in depth, and generally contains from 200 to 250 gallons of solution; the silver plates, serving as electrodes, which formerly were nailed upon frames of wood, are now generally fixed upon light iron frames, because these are not affected by the solution; two battery troughs are conveniently arranged, consisting of 6 batteries of 3 pairs intensity. The zinc plates immersed in the acid measure 6 inches by 7 inches, the exposed surfaces of which measure 84 square inches: these multiplied by 6 give 504 square inches, from which electricity is disengaged. The silver electrodes exposed to the articles receiving the deposit, vary from 3000 to 4000 square inches of surface. In some plating establishments, the batteries are placed outside the house, and the connecting-rods are brought from them into the vats, so as to preserve the workmen from the injury arising from inhaling the hydrogen gas which is given off by the zincs, as it often contains arsenic, and hence is highly injurious to health; but wherever the batteries are placed, they should not be exposed to cold, as their operation is much affected by the temperature."

ELECTRO-GILDING.

In Vol. I. p. 274, we gave, in Mr. Walker's language, a process for gilding analogous to that which is there recommended for plating, namely, by adding the oxide of gold to a solution of cyanide of potassium. The oxide is prepared by dissolving gold in three parts of hydrochloric (muriatic) acid and one of nitric acid, which forms the chloride of gold. This is digested with calcined magnesia, which precipitates the gold as an oxide; the oxide is boiled in strong nitric acid, which dissolves any magnesia in union with the former. The oxide being well washed, is dissolved in cyanide of potassium, which gives a cyanide of gold and potassium, thus:—

1. Oxide of Gold	Oxygen .	1	Potash.
	Gold . .	1	
2. Cyanide of Potassium	Potassium	1	
	Cyanogen	1	Cyanide of gold and potassium.
	Cyanide .	1	

By this method there is formed one part of potash in the solution as an impurity, not, however, very detrimental to the process. In preparing the oxide of gold there is always a little of the gold lost, to recover which, the washings should be kept, dried, and fused.

Several other modes may be followed for producing the cyanide of potassium and gold. We may add, for example, to chloride of gold cyanide of potassium, which gives a proportion of chloride of potassium in the solution. The best process is that described for silver—having a solution of cyanide of potassium with a gold positive electrode, and the negative electrode in a porous vessel also charged with cyanide of potassium. But for this process, and for all the operations of gilding by this solution, it must be heated to at least 130° Fahr. The articles to be gilt are cleaned in the same way as that described for silver, but are not dipped into nitric acid previously to being put into the gold solution. Three or four minutes is sufficient time to gild any small article. For an iron figure, or such like, the article ought to be put into strong nitric acid, to bestow upon it what is termed the passive state; that is, a condition of iron in which acids do not act upon it, first pointed out by Schoenbein, though the application of this fact to gilding was first pointed out, so far as we are aware, by Mr. Glassford. We need hardly mention here that all these processes are patented.

The solution may be heated by various methods; but that generally adopted is to put a stoneware pan containing the solution into a vessel of water, which is kept at the boiling point. The less battery power is required in proportion to the heat of the solution. If the latter is heated to 200° Fahr., one pair of plates will be sufficient; but generally three or four pairs are used, and the solution is kept at a temperature from 130° to 150° Fahr.

As iron, tin, and lead are found to be very difficult to gild direct, they have generally a thin coating of copper deposited upon them by the cyanide of copper solution, as described in our last chapter, and then they must be put immediately into the gilding solution. The process of gilding, however, is generally performed on silver articles. These, after being properly cleaned and carefully weighed, are kept in pure water until it is convenient to insert them in the gold solution. The first immersion imparts merely a blush of gold, and on receiving this they are taken out and brushed; they are then returned into the solution, and if this and the battery be in good condition, three or four minutes will suffice to impart a pretty durable coating. The solution should contain from half an ounce to an ounce of gold in the gallon, and ought to be sufficient in quantity to gild the entire article at once, as, when there is a part immersed in the solution and a part out, a line mark will generally be left at the point coinciding with the surface. The average cost of depositing gold is about 2d. per pennyweight.

When articles require to be regilt, the partial coating which remains upon them ought to be removed in the first place, either by the *dry method* of brushing, as already explained for

silver, or by what is termed the *wet method*, which consists in first immersing the articles in strong nitric acid, and then adding some common salt, not in solution, but in crystals. By this means the gold may be dissolved from any metal without injuring it in the least; and the articles must then be polished to prepare them for regilding.

The proper colour of the gilt article, when taken out of the solution, is a dark yellow, approaching to brown. When this is cleaned with the scratch-brush, it yields a beautifully rich-coloured deep gold; but if, when removed from the solution, the colour of the article is blackish, the process may be interrupted, as the article in this state will never either brush or burnish to a satisfactory colour. Every variety of shade may be imparted, according to the strength of the battery or the temperature of the solution, the colour of the gilding being light in proportion as the solution is cold or the battery weak, and dark, even to blackness, if the battery is too strong, and gas is given off from the article. By adding ammoniuret of gold to the solution, when the articles are just being put into it, a very rich dead gild is obtained. If the colour obtained by any of the processes adopted is not satisfactory, it may be improved by the following mixture, which is that adopted in the old process to colour gilding or gold; namely, 3 parts nitrate of potash, $1\frac{1}{2}$ sulphate of zinc, $1\frac{1}{2}$ alum, and $1\frac{1}{2}$ common salt. The articles are coated with a paste made of these ingredients with a small quantity of water, and are then placed upon a plate of iron over a clear fire till they attain nearly a black heat, when they are suddenly plunged into cold water. A very beautiful high colour is thus obtained, and by a variation in the mixture different hues may be imparted.

EFFECTS UPON HEALTH.

The method of gilding, before the introduction of electro-deposition, was by forming an amalgam of gold and mercury, which, at the consistence of a thin paste, was brushed upon the articles over a strong heat. This process was exceedingly pernicious to health. The mercury, being raised in vapour, produced salivation in the workmen, and various forms of disease, as paralysis, &c., which generally resulted in premature death. The average of the lives of men so employed has been estimated not to exceed from thirty to forty years; and thus the mortality existing in a somewhat extensive department of British art, was scarcely inferior to that which prevails among the wretched beings condemned to a lingering death in the quicksilver mines of Spain.

By the exercise of ordinary caution, these pernicious effects may be avoided in the processes of plating and gilding by the electro-chemical method. In operating with mercury, as in amalgamating zinc, the absence of heat in the processes renders them perfectly innocuous; for mercury is not volatilized, and therefore cannot be pernicious to health, except when exposed to a somewhat elevated temperature. Mr. Smee affirms that the fumes or gases from all the materials used in the ordinary methods of depositing copper by the battery, are rather conducive than prejudicial to health; and that, with the use of his own battery, even the gold and silver solutions may be manipulated with perfect safety. It is proper to remark, however, that too much caution cannot be used in avoiding the inhalation of the fumes emitted by the cyanide of potassium. Those who are constantly engaged in operating with this substance, unless the apartments are very carefully ventilated, are liable to loss of appetite, benumbing sensation in the head, giddiness, bleeding at the nose, temporary blindness or obscurity of vision, and general deterioration of health. "Having ourselves," says Mr. Napier, "inhaled much of the fumes of that '*ominous*' gas given off from the cyanide of potassium solution, we are not prepared to stand its advocate, but would rather warn all employed at the business, or who may in any degree have to do with these solutions, to be very careful not to use too much freedom. The hands of those engaged in gilding or plating are subject to ulceration, particularly if they have been immersed in the solution." Having then detailed the various symptoms to which we have above alluded, he proceeds—"We have been thus particular in detailing these effects, as a warning to all employed in the process; but we have no doubt that in lofty rooms, airy and well-ventilated, these effects would not be felt. Employers would do well to look to this matter; and amateurs, who only use a small solution in a tumbler, should not, as the custom sometimes is, keep it in their bed-rooms: the practice is decidedly dangerous."

These remarks specially apply to the gold and silver solutions, in which the operator must not forget that cyanogen, the principal ingredient of prussic acid, is an element; but some degree of caution should be used in operating with all the solutions, to inhale as little as possible of any of the fumes or gases emitted.

PHOTOGRAPHY, OR PHOTOGENIC DRAWING, THE CALOTYPE, DAGUERREOTYPE, &c.

CHAPTER V.

THE DAGUERREOTYPE.

We have hitherto confined ourselves to those photographic processes in which paper is the substance used for receiving the sensitive coating, and which, from the trifling expense of the materials and greater simplicity of the operations, are best adapted for beginners. Perhaps, if we were still to adhere to the rule of advancing by degrees from the less to the more complex, we should now proceed to detail the processes on glass, and likewise a variety of similar processes on paper, which are certainly considerably less tedious than those we are about to describe. But the branch of the art which is known as the daguerreotype, has justly assumed and has hitherto maintained so large and important a space in the estimation of the public, that we must proceed to describe the processes by which the very beautiful results in this department are produced, before advancing to the later improvements in the art, whether on glass or paper, which promise speedily to rival, if not to supersede, the daguerreotype for most photographic purposes.

We therefore proceed to give, in the first place, some account of the original process as published by Daguerre himself, and then to enumerate the later improvements by which the expense has been reduced, or the labour of manipulation simplified.

In following the details of M. Daguerre's process, the beginner is requested not to be alarmed or discouraged, at the first, by their apparent complexity. He will discover, in his onward progress, that much of the expense and labour may be lessened *by practising the art with a thorough knowledge of principles*, without materially detracting from the beauty of the results obtained.

The daguerreotype pictures, as is well known, are taken on polished surfaces of silverized copper. It is true, that the principal use of the copper is to support the silver foil, and thus to save the expense of a tablet of adequate thickness consisting entirely of silver; but still it is believed that the effect is actually improved by the combination of the metals. The silver used for the coating must be perfectly pure, and must be of sufficient thickness to allow of a perfect polish. The copperplate should also be of thickness sufficient to maintain a perfectly flat surface; a greater thickness is inconvenient, by adding unnecessarily to the weight. Several varieties of plates are manufactured, polished, cut to different sizes, and sold ready for use. The English plates are generally thicker, and have more silver on them than the French, so that they will bear to be repolished and cleaned a considerable number of times, and are therefore best for beginners. The French plates are, of course, the cheapest, and may therefore be employed with advantage when the operator has acquired dexterity; those marked 1·40 will scarcely admit of a second operation if the first should happen to fail; but those marked 1·30 may be carefully polished two or three times without destroying the silver.

The daguerreotype process consists essentially of five operations:—1. Cleaning and polishing the plate; 2. Rendering it sensitive to light, by exposing it to the vapour of iodine, bromine, or their combinations with chlorine, &c; 3. Adjusting the plate in the camera obscura, for the purpose of receiving

the impression; 4. "Bringing out" or rendering visible the picture, by exposing it to the vapour of mercury; and 5. Removing the sensitive coating, which has not been acted on by light, or, in other words, fixing the picture.

M. Daguerre's process consisted of these five operations. In the course of later improvements a sixth has been added, which, although not essential to the process, is found to be of great advantage—namely, more permanently fixing the picture by giving it a coating of gold.

The following are the details of the method practised by M. Daguerre:—

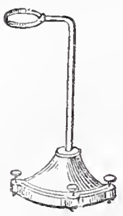
FIRST OPERATION—CLEANING AND POLISHING THE PLATE.

The materials required for this operation are—a little olive oil, a muslin bag of finely-levigated pumice, some finely-carded cotton, and a phial of nitric acid diluted in the proportion of one part of acid to sixteen parts of water. A small spirit-lamp, and an iron-wire frame, upon which the plate is to be placed while receiving the heat of the lamp, are likewise required. The wire-frame may be in the form of a square supported on three feet, or a common retort-stand may be used.

The silvered plate is first powdered with pumice by shaking the bag, and then it is rubbed with a piece of cotton dipped into the olive oil. The rubbing is performed with a circular motion, commencing from the centre of the plate, and proceeding uniformly outward without removing the cotton. When well polished, the plate is cleaned by again powdering it over with pumice, and rubbing it with *dry cotton*. It is then rubbed all over with a little cotton moistened with the nitric acid, diluted as already directed. In this last operation the cotton must be frequently changed, and the plate must be rubbed with it briskly for some time, that the acid may be perfectly diffused over the silver, for, if suffered to run into drops, it produces a permanent stain. The appearance of a uniform thin film over the surface of the silver, shows when the acid has been properly diffused; and this is then to be cleaned off with pumice and dry cotton.

The next part of the polishing process is to place the plate on the wire-frame, or on a stand of the annexed form (fig. 1), with the silver upwards, while the spirit-lamp is held in the hand, and moved about below the plate, so as to allow the flame to play upon its copper surface. When this is continued for four or five minutes, a white coating will be formed over the surface of the silver, and then the lamp is withdrawn. The plate is now taken and *suddenly* cooled, by placing it on a stone floor or a mass of metal; and, when perfectly cold, it is again polished with pumice and dry cotton. The acid must again be applied two or three times in the manner already described; and the plate must be rubbed, after each application, with pumice and dry cotton. It is of the utmost importance that the last operation be performed with the acid, immediately before the plate is intended for use; and very particular care must be taken, neither to breathe upon the polished surface, nor even to touch it with the fingers. Every particle of dust must be removed in the final operation, by cleaning with perfectly dry cotton, not only the surface of the silver, but even the back and edges of the copperplate. It is also of importance that, when just about to be used, the plate should have its grain laid in a particular direction by means of a buff, shaped like a common cloth brush, and covered either with cotton-velvet or a piece of soft doeskin. For portraits, the grain should be across the face; and for views, in the direction of the view.

Fig. 1.



In performing these operations, the plate, if too large or thin to be conveniently supported on the fingers, may be placed in a frame or holder of any suitable form—care being taken that the latter also be perfectly free from dust or grease, especially in the last part of the process. It is usual, *after the first polishing*, to fix the plate on a board, C, (fig. 2,) by means of four fillets, B B B B, of plated copper. To each of these are soldered two small projecting pieces, shown in the figure, which hold the tablet at the corners, and the whole apparatus is firmly secured by screws, as exhibited at D D D D in the detached fillet.

When the plate is polished, and is not to be immediately used, it may be protected from injury in a wooden or metal box, with grooves, similar to that represented in fig. 3.

Fig. 2.

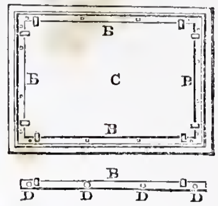
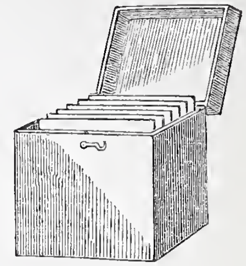


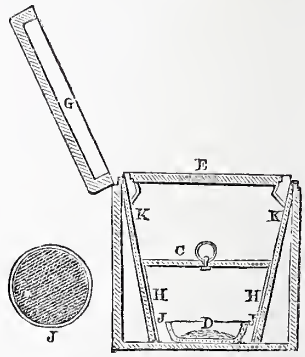
Fig. 3.



SECOND OPERATION—APPLYING THE SENSITIVE COATING.

On the care and skill with which this operation is performed, the success of the whole process chiefly depends. M. Daguerre used only the *iodine*, to form the sensitive *ioduret of silver* over the face of the tablet; but as we shall afterwards see, bromine, or other accelerating substances, are now used with the iodine. We shall confine ourselves at present to M. Daguerre's process, who used, for applying the vapour of iodine, a box of the annexed form (fig. 4). It is furnished internally with tapering sides, K, so as to be funnel-shaped within, and the capsule, D, containing the iodine, is covered with a ring, J J, on which is stretched a piece of fine gauze. This has the effect of preventing the particles of iodine from rising in the shape of dust and staining the plate, while it permits the vapour to pass freely. C is a small lid or cover, resting on supports, H, and accurately fitting the interior, so as to divide the box into two chambers. The object of this internal lid, which is never removed except when the box is in use, is to concentrate the iodine vapour, that it may act with speedier effect on the plate when the lid is removed. E is the position of the board or frame to which the plate is attached when being exposed to the vapour, and G is the lid of the box, which is kept closed except when the plate is being removed or inserted.

Fig. 4.



When the polished plate is about to be submitted to the iodine vapour, the cover C is removed, and the cup D is charged with a small quantity of iodine (half an ounce will be sufficient), broken, or comminuted into small pieces. The cup is then covered with the gauze, J; and the board, E, with the plate attached, is placed face downwards at the top of the box, where it is supported at the corners by four projecting pieces. The lid of the box being carefully closed, the plate is allowed to remain till the vapour of the iodine produces a definite golden-yellow colour. For this purpose it must be occasionally inspected, by the aid of a faint light.* If the yellow coating is too pale, the picture produced will be faint; but if the plate be so long exposed to the vapour that it runs into a violet colour, it will not be sufficiently sensitive. The plate, in the former case, must be returned to the box; but when the violet colour is assumed, it is rendered useless, and must be repolished, and the whole process repeated.

No artificial heat must be used in this operation, except for the purpose of raising the temperature of the room. Any heat applied to the box would produce a deposition of moisture, and

* Such was Daguerre's method, and such is the general practice; but we shall afterwards see that the precaution of avoiding exposure to light, in this operation, is not essential, and that it is founded on quite an erroneous assumption.

this would be completely fatal to the success of the process. To avoid any such deposition, the temperature inside the box must be the same as that of the apartment. The rapidity of effect will greatly depend upon this, and therefore, according to the season of the year, the time required for producing the required tint may vary from a few minutes to half an hour, or longer. The plate must be removed or slightly raised, and inspected from time to time, not only to discover when the proper tint has been acquired, but likewise to examine if the iodine be acting uniformly or equally on every part of the silver. Sometimes, in consequence of currents which cannot easily be avoided, the colour is produced at one part sooner than another, and, in that case, the plate must be turned a quarter or a half round, to obtain a uniform coating of the yellow or sensitive hue.

When the proper golden-yellow colour is produced, the plate is instantly inserted in a frame which fits the camera obscura, and which, as shown by the annexed figures, is furnished with a couple of doors, B B. These are represented as closed on the plate in fig. 5; and in fig. 6 they are shown as opened by

Fig. 5.

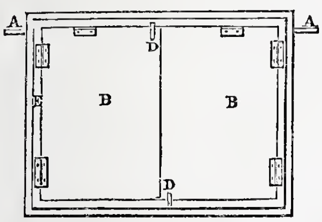
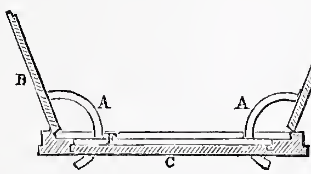


Fig. 6.



means of the half circles, A A—the means by which they are opened to expose the plate to the rays from the object, when inserted in the camera obscura. D D are stops, by which the doors are fastened till the plate is about to be exposed.

It may here be remarked, that the iodine should never be touched with the fingers, as, in afterwards handling the plate, they are apt to communicate a stain which will destroy the effect of the picture.

THIRD OPERATION—EXPOSING THE PLATE IN THE CAMERA.

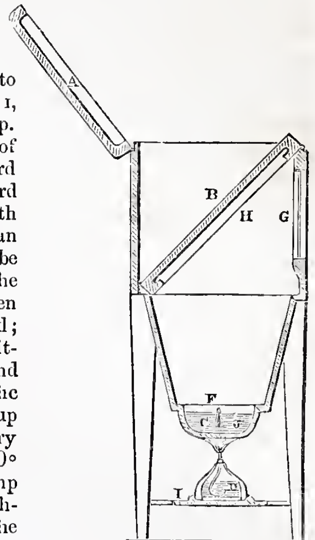
M. Daguerre recommends that the third operation should, if possible, immediately succeed the second. "The longest interval between them," he says, "should not exceed an hour, as the iodine and silver lose their requisite photogenic properties." Mr. Hunt, Dr. Draper of New York, M. Claudet, and other authorities, state that, on the contrary, the plates improve by keeping a few hours before they are used. And M. Claudet remarks, as the result of his own experience, that even after a day or two, the sensibility of the plates is not impaired.

After placing the camera in front of the landscape or object, the plate is adjusted at a proper distance from the lens by means of a ground glass. When a well-defined image is obtained, the latter is removed, and its place is supplied by the frame containing the prepared plate. The whole is properly secured by screws, and the doors of the plate-frame are then opened by means of the half circles, so as to expose the plate to the rays proceeding from the object. The time required for producing the best effect will vary with the quantity of light, the latitude, the season of the year, the hour of the day, &c. It cannot be determined by inspection, as the image impressed is invisible until the plate is subjected to the fourth process; and therefore the operator's own experience and judgment must guide him in determining the proper time of exposure. The image will be faint if the time is unduly curtailed; and, if too much prolonged, the plate will be solarized or blackened. If the first attempt should be a failure, a second operation with the same light has every chance of producing a satisfactory result.

FOURTH OPERATION—BRINGING OUT THE PICTURE.

For this operation, M. Daguerre used the apparatus represented in fig. 7. A, is the lid of the box; B, a black board with grooves to receive the plate; C, a small cup containing the mercury, J; D, a spirit-lamp; F, thermometer with bulb inserted in mercury; G, a glass through which to inspect the plate, H; and I, a stand for the spirit-lamp. The whole of the interior of the box is coated with a hard black varnish. The board with the tablet is placed, with the picture downwards, at an angle of 45°, so as to be easily inspected through the glass, G. The lid is then carefully closed; and the spirit-lamp lighted and applied to the bottom of the cup till the mercury is raised to 140° Fahr. The lamp is then withdrawn, and the thermometer will probably continue to rise, but should never be allowed to exceed 167° Fahr. The image, hitherto invisible, will soon begin to appear; and may be observed through the glass, G, by a taper; but care must be taken that the rays do not fall too strongly on the nascent image. The operation is continued till the thermometer sinks to 112°. The plate is then removed and deposited in a grooved box, or otherwise carefully excluded from the light, until it is convenient to perform the fixing operation.

Fig. 7.



FIFTH OPERATION—FIXING THE PICTURE BY REMOVING THE SENSITIVE COATING.

This operation, which has for its object the removal of the iodine from the plate of silver, so as to prevent the farther action of light, may be performed by simply immersing the plate in a saturated solution of common salt. It is better, however, to use for the purpose a weak solution of the hyposulphite of soda. M. Daguerre directs that the plate be first immersed in pure water, plunging and withdrawing it immediately, and then placed into the saline solution. To assist the effect of the latter, the plate is moved to and fro; and when the yellow colour has quite disappeared, it is lifted out and again plunged into water. In these operations, care must be taken not to touch the impression. The fixing is finished by placing the plate in an inclined position, and causing to run over it a stream of very pure water.

The drawing is now finished, and unalterable by the sun's light; but it will not bear to be brushed, and must be preserved from dust, and from contact with other substances, by placing over it a glass in a pasteboard or wooden frame.

Such is a summary of M. Daguerre's process, as given in his pamphlet and original specification. A sixth operation is now added, by which the picture is more completely protected; and several improvements have been introduced in the preceding parts of the process. These we shall now proceed to detail in the order of manipulation, having thought it desirable to give, in the first place, the process as originally published by the distinguished inventor.

LATEST IMPROVEMENTS IN DAGUERREOTYPE PROCESSES.

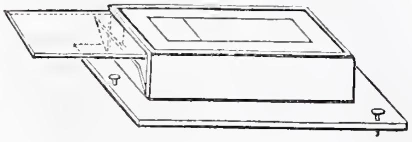
In the first operation—that of polishing the plate—we have seen that the materials used by Daguerre were highly diluted nitric acid, olive oil, and finely-levigated pumice. The following are the substances with which Mr. Thornthwaite states

that he has generally produced the best results—calcined tripoli, prepared lamp-black, rouge, and olive oil. The lamp-black must be burnt and reduced to a fine powder, and is kept, like the tripoli, in a wooden or metal box, over the open end of which a piece of the finest muslin is tied. The rouge should be the finest washed, and may be kept in a similar box. In photographic establishments, the plates are prepared in numbers by means of a lathe, to the head of which circular buffs are attached, covered on one side with folds of unbleached cotton-velvet. The use of the lathe will seldom be convenient for the amateur, but he may use with advantage the buffs, varying in size from 3 by 12, to 9 by 18 inches, according to the size of his plates. Four of these buffs are recommended to be applied in succession—the first prepared with tripoli and oil; the second and third with tripoli alone; and the fourth with prepared lamp-black, and a very small quantity of rouge. The plate is fixed by any adhesive substance in a shallow cavity on the surface of a flat piece of wood or metal, furnished with a handle at the back, by which it is briskly rubbed against the different buffs in succession. But after being rubbed on the third buff, it is heated as previously directed, in describing the first operation, and then it is finished on the fourth buff, with the prepared lamp-black and rouge. When the surface of the plate is particularly free from scratches, or not otherwise rendered difficult to polish, the use of the oil-buff may be entirely dispensed with. The utmost care should be taken, however, to see that the buffs and other polishing materials are carefully preserved from dust and damp. The buffs must be perfectly dry, and oily or greasy stains must be very cautiously avoided in the last parts of the process.

The application of the sensitive coating is a part of the daguerreotype process which has been greatly improved, both in respect of the materials and apparatus employed. Several accelerating liquids have been introduced, by the application of which, in addition to the vapour of iodine, the surface of the plate is rendered exceedingly sensitive, and portraits may be taken by even a moderate light. To procure an impression of the human features on the daguerreotype plate, it was at first recommended, and believed to be essential to the process, to paint the face white, or to dust it over with a white powder, it being presumed that the light reflected from the natural colour of the features would not have sufficient power to change the iodated surface. This has been shown to be an error, even when the iodine is used without an accelerating agent; but the process has been much improved by the aid of accelerating substances, in all of which we have combinations in various proportions of either bromine and iodine, or chlorine and iodine, and sometimes of all three. Mr. Goddard was the first who employed bromine in combination with iodine, and subsequently M. Claudet and others found that chlorine had an accelerating power, but not to the same extent as the bromine. The substances used, or recommended for the purpose, are known by the names of *eau bromée*, or bromine water, bromide of iodine, bromide of lime, Hungarian liquid, Redman's sensitive solution, Woolcott's accelerating American fluid, &c.

Of these, the amateur is free to select that which he may find the most convenient. Mr. Thornthwaite says—"The accelerating material which I have uniformly found produce the best and most certain results is a chloride of bromine, made by mixing one ounce of a saturated solution of bromine with one drachm of strong hydrochloric acid: this preparation must be kept in a stopped phial."

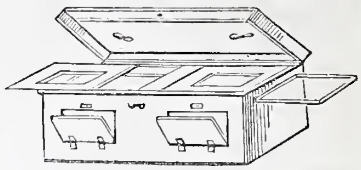
Fig. 8.



Instead of the box recommended by M. Daguerre, a couple of porcelain or glass pans should be used, the one for holding the iodine, the other the accelerating substance. The pans should be ground on the edges, and furnished with plate-glass covers, and a series of wooden or metal frames of the size of the plates to be prepared. To avoid disturbing the vapours, and thus producing an unequal coating, the pans should be made of considerable depth, and the glass covers so adjusted as to slide in grooves, in the manner represented in fig. 8. The plate is placed on the opening at the top; the slide-cover is withdrawn to permit the vapour to act, and is carefully replaced before removing the plate, when the operator wishes to do so to examine the progress of the action.

It is still better that both the pans should be mounted in a box of the form represented in fig. 9, which is termed a "bromine apparatus." At the back of the box, and therefore not represented in the figure, are two openings, corresponding to the two pans, over which is fastened a piece of white paper. Two small doors or reflectors, lined with a piece of looking-glass internally, are placed in front of the box, immediately opposite the openings in the back by which the pans are inserted. On the top of the box are two glass covers, and a series of wooden frames sliding over them, in which the plates may be inserted.

Fig. 9.



From half an ounce to an ounce of pure crystallized iodine is placed in one of the pans. In the other, if chloride of bromine is used as the accelerating agent, water is poured to the depth of half an inch, and enough of the chloride of bromine is added to bring the whole to the colour of very pale sherry. All the accelerating agents, indeed, require to be diluted with water until they assume this colour. The pans are then closed with their respective covers, and the whole apparatus is placed before a window, admitting a sufficiency of light to permit a satisfactory inspection of the progress of the action on the plate. Indeed, we shall afterwards see that any amount of light may be admitted during this operation. The plate being placed in its frame, is first deposited over the iodine pan, the plate-glass cover of which is then removed to permit the action of the vapour. The small mirror is then inclined at such an angle that, by looking into it, the white paper at the back can be seen reflected from the surface of the silver plate, and as soon as the latter has assumed a light straw colour, the cover is immediately returned over the iodine. The slide-frame holding the plate is now shifted over the pan containing the chloride of bromine; the cover is withdrawn, the mirror adjusted, and the plate exposed to the vapour till its surface assumes a deep yellow. It is then returned over the iodine again till it acquires a rose tint, when it is immediately placed in the camera frame.

A considerable number of plates may be prepared with the same dilute solution of chloride of bromine; but, instead of increasing its strength by the addition of more of the strong solution when it begins to fail, it is better to mix a fresh solution at once.

If bromide of iodine be used as the accelerating agent, the plate should remain over the iodine solution until it assumes a deep yellow tint, and over the bromide till of a deep rose colour. If Redman's solution, or the Hungarian liquid, a pale yellow and light rose will be found to answer best. Woolcott's accelerator, and the bromide of lime, both require the same tints as the chloride of bromine which we have described above. When dry accelerators, such as the bromide or chloro-bromide of lime are used, they are evenly spread over the bottom of the pan to the depth of about a quarter of an inch.

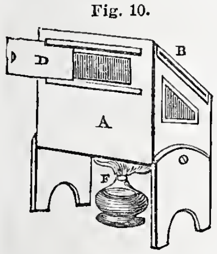
Eau bromée, or bromine water, is extensively used on the continent, and is very easily prepared, and very simple in its use. M. Fizeau directs to prepare it by putting into a bottle of pure water a great excess of bromine, agitating strongly for some minutes, and, before using, allowing the bromine to separate. A definite quantity of this saturated water is mixed with a definite quantity of pure distilled water, and thus a solution may be had of a uniform ascertained strength. The bromide of lime is produced by allowing bromine vapour to act upon hydrate of lime for some hours: this is most conveniently done by placing the slacked lime at the bottom of a flask, and then putting some bromine into a glass capsule, supported a

little above the lime. The latter will gradually assume a beautiful scarlet colour. The chloro-iodide of lime, which has a deep brown colour, may be formed in the same manner. These, and the other dry accelerators, seem to present decided advantages in very warm weather, when liquids produce a deposition of moisture on the plate.

With reference to the third operation, namely, exposing in the camera, nothing remains to be added to what we have already stated in giving the original process of M. Daguerre, beyond directing attention to the very important remarks by Sir David Brewster on the subject of camera lenses, as quoted in our third chapter. "The mode in which the exposure is effected," says Mr. Thornthwaite, "must, of course, depend upon the construction of the camera, whether it have a lens, as originally proposed by M. Daguerre, or a concave mirror or speculum, which is the apparatus patented in this country by Mr. Beard. Both kinds have their advantages. The refracting camera, as recently improved, appears to possess all the capabilities, without many of those inconveniences, which attend on the manipulation with the reflecting camera, and, being withal less expensive, is now the form generally used."

The mercurializing of the plate, after removing it from the camera, has also been already described with sufficient minuteness. In this operation, the form of box represented in fig. 10, and termed a mercury-box, is that which is now generally used. The body, A, is made of wood, and in the bottom is fixed a metal cup for holding the mercury, which is heated by a spirit-lamp, F. The plate, in its sliding frame, B, is received by a groove in the upper part of the box; and in front is a small opening, C, fitted with a piece of yellow glass, over which slides a shutter, D. From four to six ounces of pure mercury are poured into the iron cup, which is then heated by applying the lamp till the outside of the cup can just be touched by the finger without much inconvenience. The plate, in its frame, is then taken from the camera, and placed in the box; and the gradual development of the picture may be observed by removing the slide, D, and cautiously applying a lighted taper, so as to inspect the surface of the tablet through the yellow glass. The hotter the mercury is made, the more rapid the development; but a clearer and sharper outline is obtained by not accelerating the process. From five to twenty minutes is the time usually required; and if the mercury-box be supplied with a thermometer, the temperature ought to be kept at about 90°. It is important that the mercury used in this operation should be perfectly dry, and carefully purified from dust and oxide by filtering through a paper cone, with a very fine opening at the bottom.

Fig. 10.



Daguerre attached much importance to the alleged necessity of exposing the plate to the mercury at an angle of about 45°; and it will be observed that, in the drawing (fig. 10), the top of the box for receiving the plate is inclined towards the window, C. "This," says Mr. Hunt, "is perhaps the most convenient position, as it enables the operator to view the plate distinctly, and watch the development of the design; but beyond this, I am satisfied there exists no real necessity for the angular position. Both horizontally and vertically, I have often produced equally effective daguerreotypes."

To our previous directions for the fifth operation, namely, removing the sensitive coating, we have merely to add that the solution may be formed by dissolving two ounces of hypo-sulphite of soda in one pint of water. This solution is poured into a shallow vessel, and the plate quickly immersed in it, face upwards, when the coloured coating on the plate produced by the exciting agents will be observed to disappear gradually. The plate is then removed into a vessel of filtered water, to wash or dissolve away the excess of hypo-sulphite, and finally a little distilled water is poured over its surface.

This, as we have seen, concludes the daguerrotype process, as far as it was carried by M. Daguerre himself, and with several important improvements in respect to accelerating the action of the light, &c. The picture, however, in this state, although it is no longer liable to be affected by the light, is injured by the slightest touch; and hence the importance of a sixth operation, invented by M. Fizeau, which not only gives to the picture a greater security from injury, but even considerably adds to its force and beauty. This process we cannot better describe than in M. Fizeau's own words.

SIXTH OPERATION—FIXING THE PICTURE BY SOLUTION OF GOLD.

"Dissolve eight grains of chloride of gold in sixteen ounces of water, and thirty-two grains of hypo-sulphite of soda in four ounces of water; pour the solution of gold into that of the soda, a little by little, agitating between each addition. The mixture, at first slightly yellow, becomes afterwards perfectly limpid. This liquid now contains a double hypo-sulphite of soda and gold."

M. Fizeau then directs to wash the surface of the plate with alcohol, and then with water and hypo-sulphite of soda; but the washing which the plate has received in the fifth operation will suffice. He adds—

"When a picture has been washed, with these precautions, the treatment with the salt of gold is very simple. It is sufficient to place the plate on a support (see fig. 1), and pour upon its surface a sufficient quantity of the salt of gold that it may be entirely covered, and heat it with a strong spirit-lamp; the picture will be seen to brighten, and become, in a minute or two, of great force. When this effect is produced, the liquid should be poured off, and the plate washed and dried.

"In this operation the silver is dissolved, and the gold precipitated upon the silver and mercury, but with very different results; in effect, the silver, which by its reflection forms the shades of the picture, is some way darkened by the thin film of gold which covers it, from which results a strengthening of all the darks. The mercury, on the contrary, which, in the state of an infinite number of small globules, forms the lights, is augmented in its solidity and brightness by its union with the gold, from which results a great degree of permanency, and a remarkable increase in the lights of the picture."

The plate, if a large one, may be most conveniently dried by placing it on a smooth and clean piece of copper or tin plate, and while it is held in a slightly inclined position, pouring over its surface some boiling distilled water. It should then be placed on a stand, adjusted by levelling screws in a perfectly horizontal position, and will soon become quite dry. If the plate be of small size, it may be held by a pair of pliers over a spirit-lamp, while some filtered distilled water is poured over its surface. By inclining one of the corners the liquid will flow off, and the heat of the lamp, cautiously applied, will speedily dry the plate. Care must be taken to remove the lamp as soon as small bubbles of air appear on the surface of the metal.

COLOURING DAGUERREOTYPES.

The colouring of daguerreotypes, as at present practised, does not properly belong to the photogenic art. It is true that the secret of communicating natural colours to the plate by the influence of the solar light alone has lately been discovered by M. Niepce—as we shall have occasion to remark in a future chapter—but this desirable consummation of the art may possibly never be carried to any degree of perfection, inasmuch as the actual photogenic agent is not the coloured rays of the spectrum, but an invisible accompaniment of light, which, as we explained in our first chapter, is distinguished by the name of *actinism*. Colouring, however, is now so generally practised by professors of the art of photography, and communicates, when skilfully performed, so pleasing a finish to the picture, that the reader will naturally expect from us a slight notice of the subject.

We may therefore remark, that the daguerreotype pictures, when fixed or "set" by means of the gold solution, are coloured by the hand of the artist. The colours generally used are carmine, chrome yellow, and ultra-marine, representing the three primary colours, by properly combining which the artist can produce any desired tint. A small quantity of the colour, ground extremely fine, is mixed with spirit of wine, or with some dry gum or starch, and is applied with a camel's hair pencil. When used dry, as is commonly done, the

colour may be made to adhere by simply breathing on the plate. As a general rule, the colours must be very cautiously applied, and only in the smallest possible quantities, being with difficulty removed when once on the surface of the plate.

In connection with this subject, and also as indicating a substitute for M. Fizeau's gold solution in fixing the picture, we may conclude with the following remarks by Professor Page, of Columbia College, Washington:—

Some years ago, I instituted a course of experiments to determine the effects of oxidation upon the surface of daguerreotype pictures, and arrived at some beautiful results in fixing and colouring. The impression being obtained upon a highly polished plate, and made to receive, by galvanic agency, a very slight deposit of copper from the cupreous cyanide of potassa (the deposit of copper being just enough to change the colour of the plate in the slightest degree), is washed very carefully with distilled water, and then heated over a spirit-lamp until the light parts assume a pearly transparent appearance. The whitening and cleaning up of the picture, by this process, is far more beautiful than by the ordinary method of fixation by a deposit of gold. A small portrait fixed in this way, more than a year since, remains unchanged, and continues to be the admiration of persons interested in the art. One remarkable effect, produced by this mode of fixing, is the great hardening of the surface, so that the impression is effaced with great difficulty. I have kept a small portrait thus treated, unsealed and uncovered, for over a year, and have frequently exposed it in various ways, and rubbed it smartly with a tuft of cotton, without apparently injuring it; in fact, the oxidized surface is as little liable to change as the surface of gold, and is much harder. As copper assumes various colours, according to the depth of oxidation upon its surface, it follows that, if a thicker coating than the first mentioned can be put upon the plate without impairing the impression, various colours may be obtained during the fixation. It is impossible for me to give any definite rules concerning this last process, but I will state, in a general way, that my best results were obtained by giving the plate such a coating of copper as to change the tone of the picture—that is, to give it a coppery colour, and then heating it over a spirit-lamp until it assumes the colour desired. I have now an exposed picture treated in this way at the same time with the two above mentioned, and it remains unchanged. It is of a beautiful green colour, and the impression has not suffered in the least by the oxidation. Should this process be perfected, so as to render it generally available, it will be greatly superior to the present inartistical mode of stippling dry colours upon the impression; for the colour here is due to the surface of the picture itself. For pure landscapes it has a pleasing effect, and by adopting some of the recent inventions for stopping out the deposit of copper, the green colour may be had wherever desired. In some pictures, a curious variety of colours is obtained, owing to the varying thickness of the deposit of copper, which is governed by the thickness of the deposit of mercury forming the picture. In one instance, a clear and beautiful ruby colour was produced, limited in a well-defined manner to the drapery, while all other parts were green. To succeed well in the first process, viz., that for fixation and the production of the pearly appearance, the impression should be carried as far as possible without solarization, the solution of the hypo-sulphite of soda should be pure and free from the traces of sulphur,* the plate should be carefully washed with distilled water, both before and after it receives the deposit of copper; in fact, the whole experiment should be neatly performed, to prevent what the French significantly call *taches* upon the plate, when the copper comes to be oxidized.

In next chapter we shall make some remarks on the theory of the daguerreotype, and then proceed to the more advanced processes on paper and glass.

* The presence and deposit of sulphur is a fault of most of the hyposulphite of soda of commerce, and it is the action of this sulphur upon the silver that puzzles so many daguerreotypers, by clouding, staining, and marking the plates in various ways. It may be obviated by repeatedly filtering the solution, or by keeping it in lightly corked bottles a long time before it is used. In addition to the above, I may state that exposure of the coppered picture to the vapour of hydrosulphuret of ammonia, produces sometimes a pleasing effect, but usually spoils the impression.

BLOOD-RAIN, DUST-SHOWERS, AND COLOURED SNOW,

WITH SOME ACCOUNT OF THEIR MICROSCOPIC ORGANISMS.

A CURIOUS work was published by M. Ehrenberg in 1849, containing a complete record of all the known facts with reference to those extraordinary phenomena, dust-showers and blood-rain—phenomena of rare occurrence in our northern latitudes, but of which M. Ehrenberg enumerates no less than 340 in the world's history, down to the date of his publication. Of these, 81 were before Christ, and 249 during the Christian era. They appear to prevail most within a zone extending from the part of the Atlantic, off the west coast of Middle and North Africa, along in the direction of the Mediterranean Sea, extending somewhat to the north of it, and passing eastward into Asia between the Caspian Sea and the Persian Gulf. It is seldom that they reach north to Sweden or Russia. The breadth of that considerable portion of the North Torrid Zone in which they most frequently occur, is about 1800 miles.

Some of the earlier cases mentioned by Ehrenberg are of a doubtful character. The first, for instance, is the plague of blood inflicted upon the Egyptians, as related in the Mosaic history, which prevailed over all Egypt, continuing three days and three nights. The miraculous nature of that event, which occurred about 1500 years before Christ, seems to place it beyond the pale of philosophical inquiry; and similar doubts, though for different reasons, may be expressed with reference to other cases enumerated; as that, for instance, related by Virgil in the Æneid, iv. 454, about 1181 B.C., which forms the second in M. Ehrenberg's list, and one or two similar phenomena described by Homer (Ilias xi. v. 52, 54; and xvi. v. 459, 460.) The cases mentioned by Virgil and Homer may, as regards date and place, be nothing better than poetical fictions, although they are undoubtedly based on the actual knowledge or observation of real occurrences of the kind, and are so far valuable as proving that such things were not unknown in very remote times.

The other cases recorded by Ehrenberg are better attested, and some have occurred very recently—some even since the publication of M. Ehrenberg's work, bringing this curious phenomenon down to our own day. On the 31st of March, 1847, a meteoric dust-shower fell in the valley of Gastein, in Salzburg; another in Arabia, Jan. 24, 1848; another in Silesia, Lower Austria, Jan. 31. In March, 1849, a reddish dust fell at Catania in Sicily, during a south wind.

On the 14th of May, 1849, a shower of black rain fell in several parts of Ireland. It was particularly noticed at Carlow, Kilkenny, and Abbeyleix, and is supposed to have extended over an area of more than four hundred square miles. It occurred about six o'clock in the evening, and was preceded by such extreme darkness that it was impossible to read, except by candle-light. After this darkness had existed for some time, a hail-storm, attended with vivid lightning, but without thunder, occurred, and when this subsided the black rain fell. This rain was found, on examination, to have an extremely fetid smell, and a disagreeable taste; it left a stain upon some clothes on which it had fallen, and the cattle refused to drink it. A bottle of it was presented to the Royal Dublin Society, by Professor Barker. The specimen was sent from Carlow, accompanied by a letter, in which the writer mentioned that, at the time of its collection, it was uniformly black, and resembled writing ink. Professor Barker found, that, by allowing it to stand for a time, the black colouring matter separated from the water with which it had been mixed, rendering the colour much lighter than at first. The blackness of this rain was owing to the collection of carbonaceous particles in the atmosphere, and the fetid odour was due to the presence of sulphuretted hydrogen, or of decomposed animal and vegetable matter.

To come down to a still more recent date:—In a late number of the *New York Journal of Commerce*, an extract is given from the *Boston Journal*, in which it is mentioned that a fall of black snow occurred at Walpole, N.H., on the 30th March of the present year (1853). The account forwarded to Boston

was written with a solution of the snow as it fell, and had the appearance of having been written with pale black ink. It is also mentioned in the *Journal of Commerce* of the same date, that after the prevalence of a rain storm in Cincinnati, in the latter part of March, the pavements throughout the entire city were found to be strewn with a yellow substance resembling sublimate of sulphur, but which was ascertained, on close examination, to consist of pollen of flowers, wafted by the winds from a tropical region to the north. Many earth-worms were likewise deposited on the pavements by the same rain. This yellow rain extended also to Louisville, Kentucky. Yellow or sulphur showers have frequently occurred before. A description of one of them was given by De Saussure towards the close of the last century.

In the Polar voyage of Captain, now Sir John Ross, in 1818, he discovered that the snow on the cliffs of Baffin's Bay, not far from Cape Dudley Digges, was of a red colour. Many conjectures arose concerning the cause of such an unusual appearance. In a memoir read by Mr. Bauer, before the Royal Society, the true nature of this red snow was fully determined. He showed that it was of a fungous origin, that the fungi were capable of vegetating in water; but in this case the globulates produced were not red but green. He ascertained, also, that excessive cold killed the original fungi; but their seeds still retained vitality, and, if immersed in snow, produced new fungi, generally of a red colour. It is surprising that the appearance of this crimson snow, brought to light by Sir John Ross, should have been regarded by him, as well as by some of the learned men of Europe, as a marvellous display of nature, and as an event so extraordinary that the like never had been known or heard of before. The existence, however, of red snow, had been recorded centuries before by Pliny, Livy, and Aristotle; and Aristotle mentions that living beings extricated from old snow, wherein they had been engulphed, had frequently a reddish colour, which he ascribed to the influence of the snow. Martins, who accompanied the French expedition to Spitzbergen as its naturalist, some years previous to the voyage of Sir John Ross, witnessed the same phenomenon in that inhospitable region. M. De Saussure noticed it for the first time when exploring Mount Breven, in the year 1760. He afterwards found it on all the high mountains of the Alps. It was observed only in the hollows where the snow lay deep, whereas Sir John Ross beheld it on a range of cliffs 600 feet high, and which were crimsoned by it for a distance of eight miles. In 1708, when M. De Saussure was on Mount St. Bernard, he discovered it in large quantities.

On the 16th November, 1813, there fell, in the township of Broughton, in the northern part of America, so great a quantity of black powder, that it completely covered the snow which was then on the ground. This was, no doubt, analogous to the black snow which fell recently at Walpole. A substance called inflammable snow fell in Russia on the 11th April, 1832. It burned with a blue flame, without smoke.

Similar phenomena, of earlier date, are recorded on undoubted authority. In 1222 a red rain fell at Rome for one day and night; and on the 12th of August, 1623, between the hours of four and five p.m., there was a similar blood-rain at Strasburg. In Gassendi's life of Peiresc, notice is taken of a remarkable fall of red rain, which occurred in and around Paris in the year 1608. It was one of those recurrenees of *bloody-rain* which have so often awakened the wondering awe and superstition of unenlightened people. The opinion of the vulgar, countenanced by some of the theologians, was, that the appearance was produced by demons or witches shedding the blood of innocent babes. Husbandmen, who were at work in the fields, were reported to have been so astonished at the shower as to leave their labour, and fly for safety into the neighbouring houses. A shower of rain, red as blood, fell in 1849, near the village of Bonvilstone, in Wales. It was so manifest, that it impregnated the clods of earth, many of which looked like ruddle, or red chalk. The country people generally were dreadfully alarmed, and regarded it as prognosticating some coming misfortune. Others, who did not happen to witness the occurrence, came, in the course of the day, to examine the discoloured soil. Other depositions of rain have frequently happened, in which small fish, frogs, reptiles, earth-worms, molluscs, salt or brine, and, in short, any substances which have ascended into the air, have been found, and which have again been sent back to the earth's level from whence they came. An abundant rain of molluscs, genus Bulimus, took place at Montpellier, in France, in 1835, after a violent storm which came from the west. The noise of the falling shells resembled that of hail, and they might have been collected in thousands.

In 1755, the year of the memorable earthquake which destroyed Lisbon, a copious fall of red rain occurred at Locarno, near Lago Maggiore. On the 14th of October, at eight o'clock in the morning, a warm sirocco wind was blowing; at ten o'clock the air was filled with a red mist; and at four o'clock p.m. there was a blood-red rain, which left a reddish deposit equal to one-ninth of its mass. Nine inches of this rain fell in one night; it covered about 40 square German leagues, extending also on the north side of the Alps into Suabia. On the Alps it fell in the shape of reddish snow to the depth of nine feet. Humboldt states, in the *Annales de Chimie* for 1825, that when in Paramo, on the way from Bogota to Popayan, at a height of 14,700 feet, he observed a red hail. To this observation peculiar interest attaches, from the great elevation at which the phenomenon occurred, a circumstance which seems to show that the peculiar colour or constitution of the hail must have been of atmospheric origin.

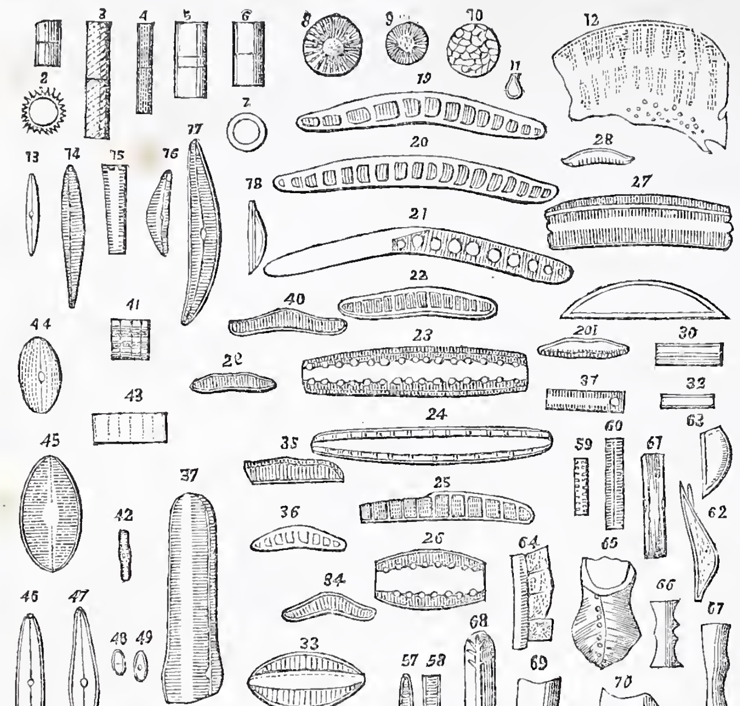
On the 13th March, 1813, while the ground was almost entirely covered with snow, there fell at Arezzo, in the department of the Arno, in Italy, a quantity of hail, not very compact, and of a reddish-yellow colour. It commenced at nine in the evening, and continued until next morning. The heaviest fall took place about three in the morning. A high wind prevailed, and lightning was visible during the night, accompanied by loud thunder. It was examined by M. Fabroni, of Arezzo. He found that it contained some argillaceous earth, with slight vestiges of carbonate of lime, iron, manganese, and silex. Depositions from the atmosphere are of an animal, vegetable, earthy, and mineral kind. Of the different colours the red predominates, or is most frequent. But the red colour of snow seems to be ascribable to a vegetable or animalcular growth inherent in the snow itself; and, analogous to it, botanists have remarked that plants bearing red flowers naturally select a white surface on which to grow. In soils of that description such plants are indigenous. The descent of those extraneous substances which have found a temporary lodgment in the air is generally rapid, like that of hail, and soon over.

On the 2d November, 1819, at half-past two in the afternoon, the wind being westerly, the heavens cloudy, and the air calm and humid, there fell, at Blankenburg, in the Duchy of Brunswick, for the space of a quarter of an hour, a copious rain of a deep red colour, which insensibly resumed the ordinary aspect of natural rain, and so continued during the rest of the day. An analysis of it was made by Messrs. Meyer and Stoop, chemists, at Bruges. One hundred and forty-four ounces of this water, perfectly transparent, of a rose colour, slightly approaching to violet, subjected to the action of heat, and evaporated to four ounces, became of a brick-red colour, and did not yield, on cooling, any precipitate. Experiments in the usual way showed that, before and after evaporation, this water was neither acid nor alkaline; but, by the addition of sulphuric acid, a very sensible disengagement of chloric acid was manifested. A solution of nitrate of silver produced a white precipitate, insoluble in boiling water, which, upon being decomposed, was recognized as a chloruret of silver. Mixed with deuto-nitrate of liquid mercury, a proto-chloruret of mercury was produced; and, mixed with hydro-sulphuret of potash, a black precipitate was obtained, in which the presenee of cobalt was detected.

Notwithstanding that snow has often acquired a reddish hue after it has fallen, yet the fall of red snow itself from the clouds is a very rare and remarkable occurrence. Such an event happened, however, in Switzerland, over a large tract of country, so lately as the 3d and 4th February, 1852. It was examined by M. Ehrenberg, who found it to yield a red precipitato,

containing a large quantity of lime and silica, a little alumina and some iron and manganese, differing in no essential respect from the chemical analysis of Ross's red snow by Peschier.

There is, perhaps, but one example of *green* snow on record, and that is given upon the authority of Martins, the naturalist. While exploring the desolate solitudes of Spitzbergen, he beheld the novel spectacle of a broad expanse of green snow. It was accompanied, however, with the *Protococcus nivalis*, giving the red colour to some of the masses. Martins decided, therefore, that the red globules of the green snow were identical with those of the red snow; that they were one and the same plant, only in different stages of development, but that it is difficult



1.—POLYGASTRICA.

1, 2, Gallionella granulata.
3 ——— decussata.
4 ——— procera.
5, 6, 7, ——— distans.
8, 9, Discoplea atmospherica.
10, Coscinodiscus?
11, Trachelomonas lævis.
12, Campylodiscus clypeus.
13, 14, 15, Gomphonema gracile.
16, 17, Cocconema cornutum (nec gracile.)
18 ——— Lunula.
19, 20, Eunotia longicornis.
21, 22 ——— longicornis.
23 ——— Argus.
24 ——— longicornis.
25 ——— granulata?
26 ——— zebrina? (Argus?)
27 ——— Monodon?
28–32 ——— amphioxys (31, *cum ovario*).
33, 34 ——— gibberula.
35 ——— zebrina?
36 Himantidium zygodon?
37 Eunotia gibba.
38 Eunotia tridentula.
39 Eunotia? lævis.
40 Himantidium Arcus.
41, 42, Tabellaria.
43 Fragilaria pinnata?
44 Cocconeis lineata.
45 ——— atmospherica.
46 Navicula Bacillum.
47 ——— amphioxys.
48, 49 ——— Semen.
50 ——— lineolata?
51 Pinnularia borealis.
52 ——— viridula.
53 ——— viridis.
54 ——— tæniata (n. sp.)
55 ——— æqualis?
56 Surirella Craticula?
57, 58, Synedra ulna.
59, 60, Fragilaria pinnata?
61 Grammatophora? parallela?
62, 63, Incerti generis (1).
64 Incerti generis (2).
65 Incerti generis (3). (Arcella costata?)

2.—PHYTOLITHARIA.

66, 67, Amphidiscus truncatus.
68 ——— obtusus.
69–71 Lithodontium furcatum.
72 ——— Scorpius.
73, 74 ——— rostratum.
75–77 ——— Bursa.
78 ——— angulosum.
79 ——— nasutum.
80 ——— triangulatum.
81 Lithostylidium clavatum.
82 *a*, ——— Serra.
82 *b*, ——— Taurus.
83–85 ——— curvatum.
86 ——— biconcavum.
87 ——— Clepsammideum.
88 Lithosphæridium irregulare.
89 Lithostylidium Clepsammideum.
——— crenatum.
91 ——— Ossiculum.
92 ——— Amphiodon.
93 ——— Terebra.
94 ——— angulatum.
95 ——— rude.
96, 97 ——— denticulatum.
98 ——— Emblema.
99 ——— irregulare.
100 Lithomesites ornatus.
101 Lithostylidium triceros.
102 ——— calcaratum.
103 ——— spiriferum.
104 ——— læve.

to state which is the original. Mr. Bauer's experiments, already alluded to, coincide pretty nearly with these inferences.

Sand showers are of common occurrence throughout a great extent, if not the entire portion, of the vast plains of China. The natives are quite familiar with this phenomenon. The showers usually occur at different intervals during the year, and at times when neither cloud, fog, nor mist obscures the heavens, but the sky presents a rusty hue, and the sun and moon have a smoky aspect. It is an impalpable yellow powder, which insinuates itself into dwelling-houses and wearing apparel, as well as into the eyes, nostrils, and mouth—is extremely annoying, and gives rise to many ophthalmic disorders. These Chinese sand showers are supposed to originate in the vast alluvial plain of Eastern Asia, known as the Desert of Gobi or Shamoh. The sand of the Sahara, in like manner, is occasionally elevated by the whirlwinds into the upper currents of the air, and this is commonly supposed to be the origin of the dust-showers deposited in the waters of the Atlantic,

twelve hundred miles sometimes, opposite to the trade winds. The Atlantic Ocean may act, therefore, as a rectifier of this arid air, divesting it of its excessive heat, and precipitating the fine, irrespirable, and noxious sand mists, which are disseminated from the sterile wastes of Africa.

Ehrenberg, indeed, to whom we are indebted for the wonderful discovery of the infusorial character of blood-rains and dust-showers, maintains that they arise from some general law connected with the earth's atmosphere, according to which there is a self-development within it of living organisms. He conceives that they cannot be traced to mineral material from the earth's surface, nor to revolving masses of dust material in space, nor even to atmospheric currents simply. However mysterious the origin which he ascribes to them may appear, it is not more so than that of meteoric stones; and it is a remarkable fact, that a simultaneous occurrence of dust-showers and falls of meteoric stones has been observed in *thirty-two* instances—eighteen appearing to have happened before the Christian era, and fourteen similar coincidences since its commencement. Can these coincidences have been accidental?

The whole number of species of organisms observed by Ehrenberg in these dust-showers is 320. The plates in his curious work contain not only figures of all the forms observed in each case, but a sketch of a portion of the dust as it lay under the field of his microscope, exhibiting to the eye the relative prevalence of different forms, and the colours they presented. A specimen of his fifth plate is annexed, exhibiting the organisms seen in a sirocco dust-shower, which fell at Lyons, Oct. 17, 1846. This shower afforded 39 species of Polygastrica, 25 of Phytolitharia, 3 of Polythalamia, besides minute portions of plants. We have given 105 out of 123 of the figures in Ehrenberg's plate, with their respective designations; and these figures may be taken as exhibiting the general character and appearance of the organisms found in dust-showers.

Dust collected by Mr. Darwin, from a shower which fell in the Atlantic, lat. 17° 43′ N., long. 26° W., about 500 miles from the coast of Africa, resembled volcanic ashes, though evidently not of that origin; and about a sixth part of it was found on minute examination to consist of siliceous shells of fresh water and land infusoria and siliceous phytolites—eighteen species of each description. The most of the forms were European—none of them exclusively African. It is a curious and notable fact, that among them was a South American species, *Himantidium papilio*, which occurs at Cayenne. Ehrenberg concludes from this, that either the dust came in part from South America in the upper regions of the atmosphere, or that the above species is yet to be discovered elsewhere.

Another dust-shower, which fell at Malta, 15th May, 1830, afforded 43 species, of which 15 were Infusorial, 21 Phytolitharia, and 7 Polythalamia. The wind, when this shower fell, was east south-east, and a similar fall of dust took place at the same time in the bay of Palmas, in Sardinia. Though some of the species which fell in this shower occur in Africa, yet there were no characteristic African forms—no positive proofs that it emanated from that continent. The common opinion, which refers such showers, with the hot winds that attend them, to the Sahara Desert, is therefore considered by Ehrenberg to be groundless. Among the species was one characteristic form from Chili.

A sirocco dust-shower fell at Genoa, May 16, 1846, in which Ehrenberg found about 50 different species, the forms having much resemblance to those of the Malta and Atlantic showers. The colour was yellowish or ochreous, from oxide of iron, and not grey, like the true African dust. It contained about $\frac{1}{6}$th to $\frac{1}{3}$d of its mass of organic matter.

On the whole, from observations extending through a period of more than twenty years, it appears that the showers of the Atlantic, of Malta, and of Genoa, are in general alike in organic as well as in inorganic constitution, and in the absence of characteristic African forms. They are all, or chiefly, of a brownish-red colour. There is no evidence of volcanic origin in these showers.

THE SCIENCE OF PHRENOLOGY.

CHAPTER V.

ORDER I.—FEELINGS.

GENUS I.—INFERIOR PROPENSITIES.—(*Continued.*)

4. ADHESIVENESS.—Dr. Gall observes on the discovery of this organ—"I was requested to take, for my collection, a cast of the head of a lady, who was, as they told me, a model of friendship. I took her cast—more out of kindness than in the expectation of making any discovery—and I endeavoured to get a correct one. On examining this head, I found two great prominences, constituting the segment of a sphere, by the side of the organ of love of offspring (Philoprogenitiveness). As, up to that time, I had never seen these prominences, which, however, were evidently formed by the brain, and exceedingly symmetrical, I considered them as a cerebral organ. But what were the functions of this organ? In order to get some general view on this point, I inquired of all the friends of the lady, respecting her qualities and faculties. I attempted to learn of the lady herself, what propensities and faculties she believed she possessed. All united in confirming what had been told me, that she had an invincible attachment to her friends. Although her fortune, at different periods, had experienced great changes, and, by degrees, she had passed from poverty to honour, her feelings for her old friends had never changed. This characteristic trait struck me. The idea occurred to me that the disposition to friendship might also be found in a particular cerebral organ. This opinion acquired with me a still greater degree of probability, as the prominences that I had observed on the head of the lady were placed immediately above the organ of physical love (Amativeness), and by the side of that of the love of offspring, and these three sentiments have some analogy with each other."*

Subsequent observations have confirmed the existence of this organ, and it is now established.

Wherever the ardour of strong attachment distinguishes itself, the individual under its influence seems almost impelled to embrace its object. If there be any true friendship in man, it will manifest itself by the firm grasp of the hand and the sparkling lustre of the eye when it meets the object of its attachment.

Perhaps one of the most striking exemplifications of Adhesiveness, under any circumstances, is evidenced in David, king of Israel, for Saul and Jonathan. Hunted as David was by Saul, and subjected to every privation which his infuriated jealousy could devise, David ever distinguished himself by attachment to the exasperated but deluded monarch. Twice might he easily have rid himself from Saul's persecution, but he spares him each time, and, by the gentle expostulations of friendship, revives, for a time at least, all the better feelings which had slumbered in Saul. The beautiful elegy over Saul and Jonathan is a fine illustration of Adhesiveness:—"Saul and Jonathan were lovely and pleasant in their lives, and in their deaths they were not divided. They were swifter than eagles; they were stronger than lions. How are the mighty fallen in the midst of the battle! I am distressed for thee, my brother Jonathan; very pleasant hast thou been unto me: thy love to me was wonderful, passing the love of women. How are the mighty fallen in the midst of the battle!" To say that the love of Jonathan surpassed the love of woman was to say much indeed, and perhaps, with the exception subsisting between Damon and Pythias, there never has been so striking an exemplification of pure Adhesiveness subsisting between men. But for all this, the faculty is more energetic in women than in men. "Man is but a rough pebble without the attrition received from contact with the gentler sex. It is wonderful how the ladies pumice a man down into smoothness, which occasions him to roll over and over with the rest of his

* Gall's Works, Vol. III., p. 300.

species, jostling, but not wounding, his neighbours, as the waves of circumstances bring him into collision with them."*

Dr. Gall observes, women are generally more devoted to their friends than men, and display an indefatigable activity in serving them. Whoever has gained the affections of a woman, is sure to succeed in any enterprise in which she assists him. Men draw back much sooner in such cases. Frequently in my life have I had occasion to admire in females the most generous zeal on behalf of their friends. Who is not astonished at the courage shown by a woman, when her husband—whose misconduct has, perhaps, a thousand times offended her—is threatened with imminent danger? Who does not know many instances of the most heroic devotedness on the part of the sex? A woman spares no effort to save her friend. When it is a question of saving her husband, her father, her brother, she penetrates prisons, she throws herself at the feet of sovereigns. Such are the women of our day, and such has history represented those of antiquity. Happy is the man who has a woman for his friend!

Nor are the sweets of friendship confined to any privileged class of mortals, in contradistinction to their brethren of mankind generally. Every upright, generous, social soul, will find a fellow-feeling glowing warmly in the congenial breast of some kindred spirit, where Adhesiveness is largely developed, whether the fleshly tabernacle thereof be arrayed in silk attire, or clad in a homely suit of russet grey—whether it stretch its weary limbs on an humble pallet of straw, or recline its pampered carnality on a gilded couch of downy softness. The same heavenly influence illumines the lowly cot of the peasant and the gaudy palace of the prince. Friendship is, indeed, the wine of human existence.

> "It is no lingerer in a monarch's hall,
> A joy it is and a wealth to all,
> It breathes of bliss over land and sea—
> Friendship, what gift hath the world like thee!"

The natural language of Adhesiveness, in its most energetic action, inclines the body sideways and backwards, so that, as nearly as possible, the head may touch the organ which is situated on the outer side of Philoprogenitiveness. This posture has been very faithfully given by the ancients. There is a beautiful group of Castor and Pollux, in which we see their arms resting on each other's shoulders, and these friends pressing together their organs of attachment.

In the Madonna of Raphael, Mary presses this region of her head against the corresponding region of the head of the child.

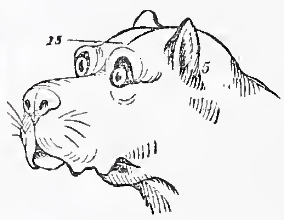
Notwithstanding all that has been said of the want of attachment of the cat, I affirm they are capable of the strongest attachment. They testify this by turning the head laterally backward, and from above downward, rubbing gently the organ of attachment against him whom they caress.

The faculty is as much distinguished from Benevolence as from Amativeness. A man may be purely benevolent, but still be an anchorite with respect to friendship. The ballad of Edwin and Angelina may serve as an illustration of this. The most degraded of characters are frequently instances of this attachment. I should think the proverb, "there is honour among thieves," may be traced to it. When it is excessively developed, it leads to despair at the loss of friends, and, if combined with large Inhabitiveness, extreme agony at being compelled to leave home and country.

5. Combativeness.—This organ is situated on either side of Philoprogenitiveness, and communicates the propensity of physical courage. Dr. Gall thus describes its discovery.† He collected a number of individuals of the lower ranks of society into his house. To gain their confidence he treated them with wine and money, and, by this means, drew from them a complete history of their various qualities, good and bad. He thus discovered many striking exemplifications of his system. During the narratives which the Doctor's wine was the means of freely-drawing forth, he was much struck with the observations and epithets of contempt which the most quarrelsome bestowed upon the meek and unobtrusive. They were stigmatized as milksops, cowards, poltroons, &c. Upon an examination of their heads, he found invariably that the parts now under review were freely and fully developed in those who used the coarsest language and displayed the most irritable feelings, while, in those who were stigmatized as cowards, the parts were generally flat, and sometimes hollow. Continuing his observations, he discovered similar developments in the heads of quarrelsome students, valiant officers, and those who were in the habit of engaging in duels. He also discovered that the heads of courageous animals were wide between and behind the ears, while those who were shy and timid presented a narrow appearance.

Fig. 17.

Fig. 18.



13 Benevolence small.
5 Combativeness large.

Fig. 19.

13 Benevolence large.
5 Combativeness small.

The organ is more fully developed in men than in women, though we read in Tacitus of a lady, named Verulana Graeilia, who abandoned her children, her kindred, and her relations, and followed nothing but the war. Dr. Gall also mentions a young lady, in whom this propensity was so energetic, that she disguised herself repeatedly in male attire, that she might engage in combat with the other sex. Combativeness is a very distinguishing feature in all polemics. He in whom it is large will seek every opportunity of indulging it, whether in the forum, the pulpit, or even the convivial party. Here is an illustration:—

> "I knew two holy friars, as holy men
> As ever snor'd in sackcloth, after sinning.
> And they were learned. What now was the upshot?
> I should have said, one's crucifix was white,
> The other's black. They plied mild arguments
> In disputation. Brother was the term
> At first; then sir; then nothing worse than devil.
> But those fair words, like all fair things, soon dropp'd
> Fists were held up, grins in the face grew rife,
> Teeth (though in these one had the better of it
> By half a score) were closed like money-boxes
> Against the sinner damn'd for poverty.
> At last the learned and religious men
> Fell to it mainly, crucifix in hand,
> Until no splinter, ebony or linden,
> Was left, of bulk to make a toothpick of."
>
> Walter Savage Landor.

Such is often the effects in religious feuds: but Combativeness makes its way, too, into the convivial party. The late justly celebrated Dr. Barclay, who was a wit and a scholar, as well as an eminent physiologist, exposed very happily the tendency to debate, on one occasion, when he was at a large party, chiefly composed of medical men. As the wine-cup circulated, the conversation accidentally took a professional turn,

* Captain Marryatt.
† Gall's Works, Vol. IV., p. 14.

and, from the excitation of the moment, two of the youngest individuals present were the most forward in delivering their opinions. Sir James Mackintosh once told a political opponent, that, so far from following his example of using hard words and soft arguments, he would, if possible, pass into the opposite extremes of soft words and hard arguments. But our young M.D.s disregarded this salutary maxim, and made up in loudness what they wanted in learning and experience. At length one of them uttered something so emphatic—I mean as to manner—that a pointer dog started from his lair beneath the table, and *bow-wow-wowed* so fiercely that he fairly took the lead in the discussion. Dr. Barclay eyed the hairy dialectician, and, thinking it high time to close the debate, gave the animal a hasty push with his foot, at the same time exclaiming, in good broad Scotch, "Lie still, ye brute! I'm sure ye ken just as little about it as ony o' them." This sally was followed by a hearty burst of laughter, in which the disputants good-humouredly joined.

There is, indeed, a great necessity to restrain this organ. It is Combativeness which gives flippancy to the tongue, which, as a high authority has observed, is a world of iniquity, and has destroyed more than the sword. The different styles of preaching, in ministers of the gospel, may be safely inferred from the moral or the animal region. Those in whom the animal region predominates, are perpetually engaged in theological strife and bitterness. Those in whom the moral region predominates, breathe the spirit of tenderness and charity to all, however much they may differ from them in doctrine. Calmness and command of temper are absolutely necessary in the investigation of any subject, but more especially of religion. It will be invariably found that persecution never answers the end of the powers that design it. Oppression naturally begets resistance. The oppression of one class of religionists, rouses the Combativeness of another. But this is not altogether without its use. It makes men more careful for true religion, and thus it is that God out of evil still educes good, causing the wrath of man to praise him, while the remainder of wrath he restrains.

In all ages this faculty seems to have been stimulated and industriously cultivated. The gladiatorial combats of the Romans were got up to stimulate and gratify this organ. They had gladiators from all countries, and these men often fought with their native weapons, and after the manner of their own country. The savage directors of these brutal exhibitions frequently took advantage of the national antipathies between the combatants, and found no way so ready for exhibiting to the populace all the bloody circumstances of a real battle, as to match together men of different nations.

Among modern pugilists, the faculty of Combativeness has been strongly exemplified; and though those brutal exhibitions, prize-battles, are not so frequent now as formerly, there are still not wanting persons—and those, too, in the highest walks of life—who bestow both time and money to obtain the gratification. It would, perhaps, be difficult to say in which of these classes, the backers or the combatants themselves, the organ most predominated. Probably self-esteem is the only means of preventing noblemen themselves (so called) from pursuing this degrading amusement.

There is a highly interesting anecdote in Mr. Selby's "History of British Ornithology," in which the force of parental affection is exhibited in birds, who were supposed totally deficient in physical energy. "A person engaged in a field not far from my residence," says Mr. Selby, "had his attention arrested by some objects on the ground, which, upon approaching, he found to be two partridges, a male and a female, engaged in a battle with a carrion crow, till it was seized and taken from them by the spectator of the scene. Upon search, the young birds, very lately hatched, were found concealed among the grass. It would appear, therefore, that the crow, a mortal enemy to all kinds of young game, in attempting to carry off one of these, had been attacked by the parent birds, and with the above singular success."

Mr. Combe observes that this organ very differently develops itself, as it respects energy, in various animals. Rabbits are more courageous than hares. The bull-dog forms a contrast, in this propensity, to the greyhound; and the head of the former is much larger, between and behind the ears, than the latter. The same difference is also discoverable between game-cocks and game-hens, in comparison with domestic fowls. Horse-jockeys, and those who are fond of fighting cocks, have long made this observation.

6. Destructiveness.—As this organ has excited more controversy than all the others put together, we feel it our duty to state the circumstances connected with its discovery, from both Drs. Gall and Spurzheim.

Dr. Gall thus states the discovery.* "By carefully comparing the skulls of animals, I found a characteristic difference between those of the frugivorous and those of the carnivorous species. Placing the skulls of the frugivora in a horizontal position on a table, and raising a perpendicular from the external opening of the ear, I found that there remained, behind this perpendicular, only a small portion of the posterior lobes and the cerebellum; consequently, the external opening of the ear, and the petrous portion of the temporal bone, mark the limits of the cerebrum in these species. Testing the skulls of the carnivorous species in the same manner, I saw that, in the most of them, the perpendicular strikes the middle of the whole encephalic mass, or, at least, leaves behind it a very large portion of the cerebral mass. Ordinarily, in the carnivora, the greatest prominence of the brain is exactly over the external opening of the ear.

"I saw, therefore, that in the carnivora there are cerebral parts above and behind the ear, not possessed by the frugivora, and the same difference I found in birds, as well as the mammifera. In all the birds of prey, this part of the brain swells out, while, in all other species of birds, it seems to retreat, and the whole brain is situated in front of the external opening of the ear. For a long while I contented myself with communicating this observation to my hearers, without making the slightest practical application of it to organology. I showed them only how, by inspection of the skull, even when the teeth were wanting, they might tell whether it belonged to a frugiverous or carnivorous animal.

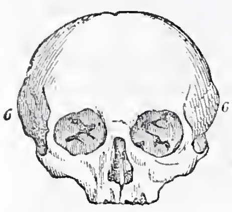
"The skull of a parricide was once sent me, which I put aside, without ever thinking that the skulls of murderers would be of use to me in my researches. Shortly after, I received the skull of a highway robber, who, not satisfied with committing robbery, had murdered a number of persons. I placed these two skulls side by side, and examined them very frequently. Every time I was thus engaged I was struck with the fact, that, though very differently formed in other respects, there was in each a prominence strongly swelling out, immediately over the external opening of the ear. The same prominence I found also in some other skulls in my collection. It appeared to me not merely accidental, that in these two murderers the same cerebral parts should be so much developed, and the same region of the skull so strongly prominent. I then began to make use of my discovery on the different conformation of the brain and skull in the frugivorous and carnivorous animals, and, for the first time, understood the meaning of the difference. The brain of the latter, I said to myself, and of the murderers, is developed in the same region. Is there any connection between this conformation and the disposition to kill? At first the idea was revolting; but when the object is to observe, and to state the result of my observations, I know no law but that of truth. Here, too, then, let us endeavour to unveil the mysteries of nature. It is only when we have discovered the secret springs of our actions, that we can learn to guide the conduct of men."

Dr. Spurzheim remarks, (Outlines of Phrenology, p. 10,) "Observation shows that violent death is an institution of nature; that the propensity to kill exists, beyond a doubt, in certain animals, and that this disposition is more or less active in particular kinds, and also in some individuals of the same species. Man, it must also be admitted, is endowed with the same propensity, for he kills almost every variety of animated beings, either to procure food or to supply his wants, while the carnivorous tribes of creation confine their destructive powers

* Gall's Works, Vol. IV., pp. 50, 51.

to a comparatively small number of kinds, and this merely to supply themselves with nourishment. Moreover, in man, this propensity offers different degrees of activity, from a mere indifference to destruction, to pleasure in seeing animals killed, and even to the greatest desire to kill. The sight of public executions is insupportable to some individuals, and delightful to others. Some highwaymen are satisfied with stealing, others show the most sanguinary inclination to kill without necessity.

Fig. 20.



"Idiots, and the insane, sometimes feel an irresistible desire to destroy all they lay hands on. Some of the insane thus affected manifest the strongest aversion to the deeds they would do, and even thank those who coerce and keep them from mischief.

"The primary nature of this propensity is a simple impulse to destroy; it does not consider the object of its application, nor the manner of destroying. It uses indifferently pointed and cutting instruments, poison, water, and fire, to accomplish its desires. It is indispensable to animals which live upon flesh. I do not, however, think that it determines the taste for this kind of aliment. The faculty is commonly more active in children than in adults, yet children generally prefer fruits and vegetables to meat.

"Besides the necessity of this instinct to procure animal food, its employment in self-defence is not only permitted by justice, but is even rewarded as a virtue. A sword is one of the emblems of state. If the faculty, however, cause the destruction of aught that should not be destroyed, it produces disorders, as when it punishes trifling crimes with death, assassinates, murders, administers poison, or sets fire to houses.

"If we place two skulls, the one of a carnivorous, the other of an herbivorous animal, horizontally, and trace a vertical line through the opening of the external ear, we shall observe that there is more brain over the ear in the carnivorous than in the herbivorous animal.

"The organ of destructiveness lies, in man and animals, immediately above the ear, and is covered by the temporal bone."

The organ is now fully established. There is no propensity in man which has more powerfully developed itself. The field of blood and strife is too frequently dignified by the term field of glory, and thousands upon thousands have recklessly rushed to it and finished their existence in literally seeking the bubble reputation, even *in the cannon's mouth.* No organ is more stimulated, or better paid for its desolating labour. "It were well if there were fewer heroes, for I scarcely ever heard of any but did more mischief than good. These overgrown mortals commonly use their will with their right hand, and their reason with their left. Their pride is their title, and their power puts them in possession. Their pomp is furnished from rapine, and their scarlet is dyed with human blood. If wrecks, and ruins, and desolations of kingdoms are marks of greatness, why do we not worship a tempest and erect a statue to the plague? A panegyric upon an earthquake would be every jot as reasonable as upon such conquests as these."* Man is, in this respect, below the standard of the fiercest of the animal tribe. It seems reserved for the most intellectual beings to fall, in this respect, below the level of the most savage, and that he delights in carnage is too notorious to all who have read the history of the Peninsular war to be doubted. Man may justly be entitled the great destroyer and exterminator of life, without regard to time, place, or circumstance. By his power the strongest are overcome; by his ingenuity the most subtle are circumvented, and their energies of body and mind made subservient to his necessities or pleasures. He is superior to the whole animal kingdom in the noblest attributes, but he enjoys one pre-eminence for which even the lowest have no cause to envy him. All the destructive animals fulfil their dire offices upon creatures belonging to other kinds. When the lion leaps from his ambush, it is in the neck of the wild ox or the antelope that he buries his claws. When the wolves howl in unison, it is the deer they are pursuing. When the scream of the eagle sounds shrillest, then let the wild duck beware. Even the insatiably ferocious tiger keeps aloof from his brethren of blood. But when the drums roll and the trumpets clang, when the banner folds are shaken abroad upon the air, and the neigh of the charger re-echoes the deep notes of the bugle, then is man, with his boasted reason, preparing to spill the blood of his brother; to drive his desolating chariot over the faces of his kindred; spread havoc and despair before his path, and leave famine and pestilence to track his footsteps.

It has been computed that 82 per cent. of the whole public expenditure of Great Britain is offered at the shrine of war, and a member of parliament once stated in public, that every working man in this country, labours, on an average, two hours a day, for the support of our warlike establishments.† While such a premium is offered for the cultivation of this propensity, is it to be wondered at that it so fearfully predominates? If we go through the length and breadth of the land, we scarcely find a testimonial raised in public to those who have spent their lives in bettering the condition of their fellow-creatures, and in devising means for saving life. But what large town will you visit, where the warrior has not his triumphal pillar, or his triumphal arch, or his equestrian statue? How loud are the songs of glory, the pæans of triumph for the victor chief, but alas! how sad to the dying soldier!

SONG OF THE SWORD.

Weary, and wounded, and worn,
Wounded, and ready to die,
A soldier they left all alone and forlorn,
On the field of the battle to lie.
The dead and the dying alone
Could their presence and pity afford,
Whilst with a sad and terrible tone
He sang the song of the sword.

Fight—fight—fight!
Though a thousand fathers die;
Fight—fight—fight!
Though thousands of children cry:
Fight—fight—fight!
While mothers and wives lament!
And fight—fight—fight!
Whilst millions of money are spent.

Fight—fight—fight!
Should the cause be foul or fair;
Though all that's gain'd is an empty name,
And a tax too great to bear:
An empty name, and a paltry fame,
And thousands lying dead;
Whilst every glorious victory
Must raise the price of bread.

War—war—war!
Fire, and famine, and sword;
Desolate fields, and desolate towns,
And thousands scatter'd abroad,
With never a home and never a shed,
Whilst kingdoms perish and fall,
And hundreds of thousands are lying dead,
And all—for nothing at all.

War—war—war!
Musquet, and powder, and ball;
Ah! what do we fight for?
Ah! why have we battles at all?
'Tis justice must be done, they say,
The nation's honour to keep;
Alas! that justice is so dear,
And human life so cheap.

War—war—war!
Misery, murder, and crime,
Are all the blessings I've seen in thee
From my youth to the present time.
Misery, murder, and crime—
Crime, misery, murder, and woe:
Ah! would I had known in my younger days
A tenth of what now I know.

Ah! had I but known in my happier days,
In the hours of my boyish glee,
A tenth of the horrors and crime of war,
A tithe of its misery;
I now had been joining a happy band
Of wife and children dear,
And I had died in my native land,
Instead of dying here.

And many a long, long day of woe,
And sleepless nights untold,
And drenching rain, and drifting snow,
And weariness, famine, and cold;

* "Pearls of Great Price," edited by J. Elmes.

† Peace Advocate.

And worn out limbs, and aching heart,
And grief too great to tell,
And bleeding wound, and piercing smart,
Had I escaped full well.

Weary, and wounded, and worn,
Wounded and ready to die,
A soldier they left all alone and forlorn,
On the field of the battle to lie.
The dead and the dying alone
Could their presence and pity afford,
While thus with a sad and a terrible tone
(O would that these truths were more perfectly known!)
He sang the song of the sword.

With these frightful examples before us, it is impossible to deny the existence of Destructiveness in excess. Not that God has implanted in man a propensity to destroy his fellow-creatures—that is not the case; the propensity was given to assist him to subdue the earth; to have dominion over the fish of the sea, over the fowl of the air, and over every living thing that moveth upon the earth. But man has unhappily abused the power he was endowed with, and has achieved the bad eminence we have already described.

How then, let us now inquire, can this propensity be kept within its legitimate boundaries, and subjected to proper control? We answer, and speaking phrenologically, the superior religious and moral sentiments, Conscientiousness, Veneration, Benevolence, Cautiousness, and Love of Approbation, must be cultivated. Here we see the necessity of a good education and proper training. To control the destructive propensity and keep it within the sphere where its functions may be legitimately exercised, the Holy Scriptures must be the best guide. Here we are forewarned that we must not give the rein to our licentious appetites. The command, "Thou shalt not kill," is as imperative now as when first promulgated. But the same command, as illustrated by our Redeemer, "I say unto you, whosoever is angry with his brother without a cause," may well induce us to reflect upon the solemn truth, that whosoever "hateth his brother is a murderer." Anger, when in its malignant and unbridled exercise, is indeed the parent of many sorrows. Every one that is angry with his brother without a cause, stimulates to undue action Destructiveness, and if Self-Esteem did not rise up to protect the object of his hatred, he would certainly effect his destruction. We do not say it is possible for a man to be entirely exempt from the passion of anger; he would not be a man if he were. Perfect love can only be associated with a perfect being; that Being is God; therefore, God is Love! A man may feel anger, but still not be revengeful, or harbour malignant feelings. A man may be a good man, and yet be strongly endowed with Destructiveness, in the phrenological sense of the word; which implies physical energy, determined to overcome in a righteous cause:—

"E'en the good patient man, whose reason rules,
Rous'd by bold insult and injurious rage,
With a sharp and sudden check, th' astonish'd sons
Of violence confounds. Firm as his cause,
His bolder heart in awful justice clad,
His eyes effulging a peculiar fire;
And as he charges through the prostrate war,
His keen arm teaches faithless men, no more
To dare the sacred vengeance of the just!"

A man of this description is angry and sins not: he lets not the sun go down upon his wrath. In this sense only can anger be tolerated. In this sense the just man figuratively breaks the jaws of the wicked.

Anger has its origin in this organ, whatever the predisposing cause may be. One man, in whom Destructiveness is powerfully developed, and Cautiousness but moderate, feels an insult rush almost momentarily to the head. His countenance becomes flushed by the rushing of the blood upwards, his eyes emit an almost preternatural lustre, and the lightning glance which is darted upon the aggressor is frequently more powerfully felt than a torrent of harsh language. Another, in whom Cautiousness is large, presents a totally different appearance. An ashy paleness overspreads the countenance, the fists are clenched, the teeth become almost imbedded in the lips, and these are sometimes bitten to the effusion of blood. Cautiousness may prevent the violence of ebullition, but the feelings are not the less seriously wounded.

Anger sometimes proves fatal, the severity of its shock at once suppressing the action of the heart, or, as occasionally has happened, causing an actual rupture of this organ, or some of the large blood-vessels. Apoplexy, hemorrhages, convulsions, or other grave affections, may also succeed to it, speedily terminating existence.

"The celebrated John Hunter fell a sudden victim to a paroxysm of anger. Mr. Hunter, as is familiar to medical readers, was a man of extraordinary genius, but the subject of violent passions, which, from defect of early moral culture, he had not learned to control. Suffering during his last years under a complaint of the heart, his existence was in constant jeopardy from his ungovernable temper, and he had been heard to remark, that "his life was in the hands of any rascal who chose to insult him." Engaged one day in an unpleasant altercation with his colleagues, and being peremptorily contradicted, he at once ceased speaking, hurried into an adjoining room, and instantly fell dead."—*Mental Hygiene.*

Destructiveness displays itself sometimes in a place, and through a medium, where, upon reflection, one would have thought it could never have entered: we allude to the pulpit. The mild spirit of Christianity calls upon us to hate nothing but evil, and he, among Christians, who is constantly terrifying his hearers into submission by the thunders of his own destructive energy, seldom fails to represent the Divine Being as altogether such a one as himself. Much as the denunciations of certain divines is to be reprobated, it is too unhappily true, that where in clergymen this faculty is large, it indulges in coarse and bitter invective, fierce and angry denunciation, and sometimes cruel and insulting irony, totally at variance with the pacific principles of the gospel, and alike derogatory to the character of God, as it is justly abhorred by all well-regulated minds. "How different (says Dr. Calwell of America) is the temper and spirit of Christ from that miserable substitute for Christianity, that revolting caricature of piety, whining, coarse, obstreperous, and denouncing, which so assails us in some places of worship, and which has its source as exclusively in the animal organs, as the uproar of the bacchanalian, the shout of battle, or the howling of wolves! This indecent storminess of instruction affects only the animal propensities of the brain, because, as just stated, it is itself grossly animal; and we venture to assert that no teacher or minister ever practised it, who was himself largely developed in the moral and reflecting faculties—we mean, in whom those compartments fairly predominated, and gave character to the individual. On the truth of this we would be willing to peril the fate of Phrenology. It is a cast of pulpit pugilists alone, with heads of the true animal mould, or nearly approaching to it, that deal in nothing but discourses of terror, who, in sermonizing or otherwise, exercise their combative and destructive faculties to draw their flocks into the pale of their religion, precisely as they would employ a whip or a goad to drive sheep into a fold, or black cattle into their stalls. Terror is their chief, if not their only instrument of reform, and a worse can scarcely be imagined. Their appeal is to Cautiousness, the organ of the craven passion of fear, whose influence never infused morality or religion into any one, and never can. Their plea of conversion and worship is not gratitude for existence and all its enjoyments, nor yet the love of moral purity and holiness, but the dread of punishment. They would frighten sinners into heaven, as a mere refuge from a place of torment."

We hesitate not to say, that no such slavish inducements are necessary. We are persuaded, if ever a man enters into the heavenly kingdom, it must be because he loves God with all his heart and soul: and loving Him, he loves peace, purity, and order, and, from these, desires to be an inhabitant of that kingdom where they can be enjoyed in all their fulness. A Christian doctrine should never be maintained with an anti-christian spirit. In endeavouring to convince, we must be cautious not needlessly to irritate, lest the adversary's unfavourable opinion of religion be augmented by the faults of the champion, and lest he attribute to the former passions, sentiments or feelings emanating only from the animal organs of the latter.

INORGANIC CHEMISTRY.

(Continued from Vol. I. p. 546.)

CHAPTER VII.

LAWS OF COMBINATION AND DECOMPOSITION—NOMENCLATURE AND SYMBOLS.

The various non-metallic elements having been already described, we proceed to treat of their more important compounds. To make this part of the subject clearly intelligible, it will be necessary to explain at some length the laws of combination. As soon as the art of analysis had made sufficient progress, it was found that a pure specimen of any given substance contained always the same elements in the same proportion. Thus, a sample of common salt, pure and dry, consists of 23·3 parts by weight of sodium, and 35 of chlorine. On comparing together the composition of different substances, a new and remarkable relation was discovered. The quantities, namely, in which bodies mutually combine, may be expressed by proportional numbers. Thus 8 parts of oxygen unite with 1 of hydrogen, 16 of sulphur, 35 of chlorine, 108 of silver, &c. Again, 1 part of hydrogen unites with 16 parts of sulphur and 35 of chlorine; 108 parts of silver with 35 of chlorine, and with 16 of sulphur. These numbers, which might of course be increased or diminished at pleasure, as long as their respective proportions remain unaltered, are called the equivalents, atomic weights, or combining weights, of the various bodies. In the following table, hydrogen, which has of all substances the lowest combining weight, is taken as unity:—

TABLE OF ATOMIC EQUIVALENTS.*

Hydrogen,	1·	Didymium,	50·
Glucinum,	4·7	Rhodium,	52·2
Carbon,	6·	Ruthenium,	52·2
Lithium,	6·5	Palladium,	53·3
Oxygen,	8·	Cadmium,	56·
Boron,	10·9	Tin,	58·
Magnesium,	12·	Thorinum,	59·6
Aluminum,	13·7	Uranium,	60·
Nitrogen,	14·	Tellurium,	64·2
Sulphur,	16·	Barium,	68·5
Fluorine,	19·	Vanadium,	68·6
Calcium,	20·	Arsenic,	75·
Silicon,	21·3	Bromine,	80·
Zirconium,	22·4	Tungsten,	92·
Sodium,	23·	Platinum,	98·7
Titanium,	25·	Iridium,	99·
Chromium,	26·7	Osmium,	99·6
Manganese,	27·6	Mercury,	100·
Iron,	28·	Lead,	103·7
Cobalt,	29·5	Silver,	108·1
Nickel,	29·6	Iodine,	127·1
Phosphorus,	31·	Antimony,	129·
Copper,	31·7	Tantalum,	184·
Zinc,	32·6	Gold,	197·
Chlorine,	35·5	Bismuth,	208·
Potassium,	39·2	Niobium,	?
Selenium,	39·5	Pelopium,	?
Strontium,	43·8	Erbium,	?
Molybdenum,	46·	Terbium,	?
Cerium,	47·	Norium,	?
Lantanum,	47·	Ilmenium,	?

The third law of combination yet remains—certain groups of bodies, it was observed, contained the same two elements in different proportions. This might, at the first glance, seem a departure from the law just laid down, but, on further examination, the apparent discrepancy vanishes. These various quantities follow a constant and definite ratio. If we call two bodies A and B, then A unites either with 1, 2, 3, 4, 5, &c., of B, or else with 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, &c. Some elements observe the former of these series, and others the latter. More complicated proportions are rarely observed, nor is, at least in inorganic compounds, a single equivalent of one element often united with more than 5 of another. As an example of the former series, we may take the compounds of nitrogen and oxygen:—

14 parts nitrogen with 1×8 oxygen = 1 eq. nitrous oxide.
" " 2×8 " = 1 eq. nitric oxide.
" " 3×8 " = 1 eq. hyponitrous acid.
" " 4×8 " = 1 eq. nitrous acid.
" " 5×8 " = 1 eq. nitric acid.

* The equivalents of many of the metals have been already given. The above table, however, includes also non-metallic elements, and is corrected in accordance with the most recent discoveries.

The oxides of manganese illustrate the second series:—

27·6 manganese with 1×8 oxygen = 1 eq. protoxide of manganese.
" " $1\frac{1}{2} \times 8$ oxygen = 1 eq. sesquioxide of manganese.
" " 2×8 oxygen = 1 eq. binoxide of manganese.

The equivalent of a compound body is found by adding together the equivalents of its components. Various highly interesting numerical relations occur among the equivalents of such elements, as are in other respects analogous. These relations are of three kinds. The equivalents of similar elements are either nearly alike, or they are in multiple proportions, or they differ by certain increments. Thus chromium, 26; iron, 28; manganese, 27·6; cobalt, 29·5; nickel, 29·6. Again, palladium, 53·3; rhodium, 52·2; ruthenium, 52·2; platinum, 98·7; iridium, 99; osmium, 99·6; cerium, 47; lantanum, 47; didymium, 50. The metals of these respective groups are not only similar in properties and atomic weights, but generally occur together in nature.

Of multiple proportions we have likewise various examples. The platinum group has double the weight of the palladium group, and gold double that of platinum. Boron is 10·9; silicon, 21·3: oxygen, 8; sulphur, 16. The following group is more remarkable:—

		Actual Equiv.
Titanium,	$2 \times 11·5 =$ 23·	25·
Molybdenum,	$4 \times 11·5 =$ 46.	46·
Tin,	$8 \times 11·5 =$ 57·5	58·
Vanadium,	$6 \times 11·5 =$ 69·	68·6
Tungsten,	$8 \times 11·5 =$ 92·	92·
Tautalum,	$16 \times 11·5 =$ 184·	184·

The members of these groups do not occur in company.

The third relation is where an element, having an equivalent intermediate between those of two other elements, is intermediate also in its properties. Thus the alkaline metals:—Lithium, 6·5; sodium, 23; potassium, 39·2. The alkaline earthy metals:—Calcium, 20; strontium, 43·8; barium, 68·5. The halogens: — Chlorine, 35·5; bromine, 80; iodine, 127·1. The analogues of sulphur:—Sulphur, 16; selenium, 32·5; tellurium, 64·2. The members of the two latter groups are found associated in nature.

As the equivalents of the various elements are determined with increased accuracy, it is very probable that these, and other numerical relations, will become more distinctly perceptible. There is every reason to believe that the law of definite proportions extends its influence much farther than it has been yet recognized. Thus the numerical relations observed among the parts of animals and plants, and even the ratios detected between the orbits of the planets, appear all to point in this direction. Upon considerations as yet so rudimentary and incomplete, it would be of course improper to enlarge in a work like the present; yet, if we admit (as appears probable from recent investigations) that the combining molecule of water consists of 36 atoms, we see at once why hexagonal forms predominate in the particles of snow and ice, as well as in certain crystals containing much water; why endogenous plants (palms, grasses, &c.), in which the aqueous tissue predominates over the carbonaceous, principally affect the number 6, with its multiples and submultiples; why the water of the ocean contains 2·77 per cent. of salt to 97·23 water, each particle of *saturated water* (or brine, containing 27 per cent. of salt) being enveloped in 2×6 particles of water. Analogous relations might be pointed out between the water and the solid matter in urine, blood, and other liquids in the animal economy.

Hydrogen, the lightest body known, has at the same time the lowest equivalent. Now Prout, in his memoir on the relation between specific gravity and atomic weight, draws attention to the fact, that the equivalents of many important elements are multiples, by whole numbers, of that of hydrogen. It is maintained by some chemists that this law extends to all bodies, and that the fractional numbers, met with in our tables of equivalents arise merely from imperfect observation. Before this question can be finally decided, the commonly received atomic weights must be re-examined with the utmost accuracy. The whole conception is likewise faulty, unless hydrogen, the lightest body at present known, is actually the lightest in existence; a circumstance which we have no direct means of ascertaining.

These three laws of combination are often, though improperly, denominated the "atomic theory." This is a complete error. The laws themselves contain nothing of a hypothetical nature. They are the simple and bare enunciation of facts, which all inquirers must admit, whatever supposition may be framed to account for their existence and universality. One of these suppositions is the so-called "atomic theory," a view of the constitution of matter held by Democritus, Leucippus, Lucretius, and other ancient philosophers, and revived, in a somewhat modified form, by the illustrious Dalton, in order to account for the laws of chemical combination. According to this view, matter is composed of a number of minute particles or atoms, practically, though not ideally indivisible, not absolutely in contact with each other, but maintained at certain distances by attractive and repulsive forces, just as the sun and planets are kept in their position by means of gravitation. The atoms or ultimate particles of bodies differ in weight, and the equivalent number expresses their relative proportion, although the absolute weight of any atom is of course unknown. That it must be exceedingly minute appears from the researches of Thomson, who has ascertained that the weight of an atom of lead cannot be larger than $\frac{1}{310,000,000,000}$ of a grain, whilst that of the sulphur combined with it in the form of sulphuret, cannot exceed $\frac{1}{2,015,000,000,000}$ of a grain. When two bodies combine together, their atoms are arranged side by side at greater or smaller distances, their mutual approach influencing the density of the resulting body.

Others, again, deny the existence of atoms. They consider matter as continuous and homogeneous, without particles and interstices. Combination depends, therefore, not on the juxtaposition of atoms, but on the interpenetration of the components. The smallest conceivable part of a compound substance would, according to this doctrine, contain its components in the same proportion as the whole mass; or, more consistently speaking, two simple bodies, on combining, cease to exist, and are reproduced when decomposition ensues.

But if, with the majority of philosophers, we admit the existence of atoms, it still appears probable that combination takes place rather between molecular groups than between individual atoms. Dumas, in his "Philosophie Chimique," states various reasons for supposing that the particles into which bodies are resolved by heat, are larger than those produced by means of chemical action. The former class he styles *physical*, the latter *chemical*, atoms. Nor is this all. It has been mentioned in a previous article, that the specific heat of many elementary bodies, such as iron, zinc, sulphur, mercury, multiplied by the atomic weight, yields a constant quantity. But in other bodies, such as bromine, arsenic, iodine, gold, antimony, silver, this quantity is doubled. Hence it is concluded, that in these instances the ultimate atomic weight is only half of the combining proportion. Thus, therefore, we have three distinct classes of molecules differing in magnitude, the two larger of which at least cannot be ultimate atoms.

COMBINATION BY VOLUME.

Not only do the weights of bodies which combine exhibit a definite numerical relation, but the same holds good likewise with their bulk or volume. Shortly after the above-mentioned laws of combination were established by Dalton and Berzelius, it was observed by Gay-Lussac that gaseous bodies combine with each other in very simple proportions. Thus 100 volumes hydrogen, unite with 50 volumes oxygen; 100 volumes ammoniacal gas, with 100 hydrochloric acid gas; 100 volumes nitrogen, with 300 volumes hydrogen. Gases, in short, unite in the ratio of 1 to 1, 1 to 2, 1 to 3, &c. On further examination, the same law was extended to vapours, and, more recently, even to liquids and solids. The volumes of compound gases and vapours bear likewise a simple ratio to the volumes of their elements, and the law of multiples relates to combining volumes no less than to combining weights.

From observing the identity of the combining volumes of hydrogen, nitrogen, and chlorine, it was supposed that the atoms of all elements must be of the same magnitude; and hence, taking into account the supposition that the mutual repulsion between the particles of elements is equal, it was again concluded that equal volumes of the elements in a gaseous state must contain an equal number of atoms. This hypothesis was again made use of in determining equivalent weights, and led to the assumption that water, which contains two volumes hydrogen gas, united to one of oxygen, should be viewed not as a compound of one atom of each, but of two of the former element with one of the latter. It has been, however, ascertained by Dumas and Mitscherlich, that equal volumes of the elementary gases do not, in all cases, contain the same number of atoms.

Before taking leave of the laws of definite combination, whether by weight or volume, we cannot refrain from observing that the importance of the subject, though undeniably great, has at times been overrated. "When given bodies are made to act upon each other under determinate circumstances, the theory of definite proportions does not in itself enable us to foresee, amidst all the cases which the composition of the bodies would allow, to what decompositions and recompositions the general reaction will give rise, which, in fact, constitutes the main question. The doctrine of definite proportions will not acquire its full scientific value, until it can be connected to a satisfactory totality of truly chemical laws, of which it will then naturally form the indispensable numerical complement."

COMBINATION AND DECOMPOSITION.

With the general ideas entertained concerning affinity, the reader has been already made acquainted in a previous chapter. It may, however, be added, that this affinity (if we must still continue to use such a term) appears not to be, like gravitation, a fixed and unalterable property of the various elements, but to be modified according to the nature of the bodies present. Whether two bodies combine or not, depends to a great extent upon the circumstances in which they are placed; heat, light, electricity, pressure, life, time, the presence of a third body, all interfere with the general action of affinity. The so-called *nascent state* is a remarkable instance in point. Chlorine gas, previously prepared, and collected in a receiver, has little or no action upon gold; but if it be allowed to act in the moment of its liberation from some other compound (as when nitric and hydrochloric acids are mixed together), the gold is converted into a chloride, and dissolved. The same rule holds good to a greater or less extent with all bodies; their tendency to enter into combination is much more energetic at the moment of their being set free. Nitric acid is incapable of dissolving platinum; but if the latter be alloyed with silver, the whole mass becomes soluble. Iron, in its ordinary state, is little affected by the oxygen in the atmosphere; but if reduced from its oxide at a low temperature by hydrogen gas, it ignites spontaneously when exposed to the air, and burns like tinder. Platinum, in the loose porous state, usually called platinum-sponge, has a remarkable effect in promoting the union of gaseous bodies. If exposed to a current of oxygen and hydrogen, it speedily becomes red-hot, and ignites the mixture. If perfectly clean, it kindles hydrogen gas—the principle upon which Dœbereiner's machine for producing fire depends. It gradually converts the vapour of alcohol into vinegar. The explanation of these interesting phenomena is very simple. Gaseous bodies are prevented from uniting by their elasticity. If this is overcome, there is no impediment to the action of their mutual affinity. Now all bodies of a porous texture, such as charcoal, gypsum, pulverized earth, and especially spongy platinum, have the property of condensing gases and vapours, sometimes to a vast extent, and retaining them in their interstices in a state probably approaching to liquidity. In this state, the elasticity of the gases being overcome, they are enabled to enter into combination, if their affinities be at all energetic. We shall make further allusion to this subject in the sequel. The metal chromium, in its more compact state, resists the action of boiling aqua-regia (nitro-muriatic acid), and hydrofluoric acid, and of potash and nitre at a red-heat. When in a state of minute division, it readily dissolves in hydrochloric acid.

In a compound body, the properties of the components are

modified, neutralized, and to a greater or less extent suspended. But we must not suppose them annihilated. The sulphuric acid in gypsum, or in Epsom salt, is unable to corrode wood or to dissolve metals; but its power is no more destroyed than is the weight of a leaden hall suspended over a pulley by means of a counterpoise. Remove the latter, and the ball immediately falls to the ground. Remove, in like manner, the lime or magnesia from the salts just mentioned, and the acid at once exerts those properties which have heen temporarily masked hy an antagonistic power. As soon as the equilibrium which exists between the ingredients of a compound is overcome, decomposition ensues. This result may be brought about by a variety of means. Heat, light, and electricity, though they powerfully aid comhination, are, under other circumstances, no less active in promoting decomposition. Compound bodies are frequently broken up by contact with another substance possessing a powerful affinity for one of their ingredients. Often, again, this action is reciprocal; two compound substances mutually decompose each other, and exchange their constituents. A foreign body may sometimes break up a compound by its mere presence, without seizing upon any of the liberated ingredients. A body undergoing decomposition may, in like manner, disturb the equilibrium of another compound with which it is placed in contact. Thus, silver in filings decomposes the peroxide of hydrogen without being itself affected. Protoxide of mercury decomposes peroxide of hydrogen, and is itself at the same time reduced to the metallic state. The action of ferments will be considered on a future occasion. Even mechanical causes may determine the decomposition of certain compounds. Thus, a solution of the permanganate of potash is rapidly decomposed if filtered over clean sand, or boiled with fragments of Berlin ware. Vibration is likewise a decomposing agent, as is proved by the well-known fact of beer being turned sour by thunder, the discharge of artillery, and even the beating of drums.

The influence of time upon chemical phenomena has been hitherto very little studied. We have, as yet, concerned ourselves only with the final results of a reaction when the process is over, and a state of equilibrium established. What successive changes precede the attainment of this consummation we have overlooked, assuming the reaction to be instantaneous, as far as the *quality* of the products is concerned. In other words, we have estahlished the *statics*, but not the *dynamics* of chemistry; the doctrine of molecular equilibrium, but not that of molecular motion. Yet some phenomena have been observed, which clearly prove that a given agency, sufficiently prolonged, may yield, not merely a greater amount of the product first generated, but something differing totally in kind. Thus, if effloresced oxalic acid be dissolved in hot alcohol, the solution, on cooling, deposits the greater part of the acid in crystals. But if the liquid be kept for some months at a temperature of 104° (122° F.), this is no longer the case, and the presence of oxalovinic acid and oxalic ether becomes manifest.

NOMENCLATURE AND SYMBOLS.

The principles of chemical nomenclature are exceedingly simple. The compounds formed by any element with oxygen are called oxides or acids. Those containing 1 equivalent of oxygen, are protoxides; those with 2, binoxides; with 3, teroxides, with $1\frac{1}{2}$, sesquioxides; with $\frac{1}{2}$, dinoxides. The highest degree of oxidation, if not an acid, is sometimes called a peroxide. In forming the name of a compound, the electro-negative element, or that which, in the electro-decomposition of the body, would appear at the positive terminal, is placed first. Thus we say, oxide of chlorine, chloride of iodine, iodide of sulphur, sulphide (or sulphuret) of sodium, and not chloride of oxygen, iodide of chlorine, sulphuret of iodine, sodiuret of sulphur. The names of acids terminate in *ic*. If an element form two different acids with different proportions of oxygen, the name of the one with the smaller amount of oxygen terminates in *ous*. If a greater number of acids occur, the syllable *per* is prefixed; thus *perchloric* acid, a compound containing more oxygen than chloric; or *hypo*, as *hyposulphurous* acid, containing less oxygen than the sulphurous. The compounds of chlorine are called chlorides; those of iodine, iodides; those of sulphur and phosphorus, sulphides and phosphides (formerly, sulphurets and phosphurets). If the name of an acid ends in *ic*, those of its salts have the termination *ate*, but if they end in *ous*, they terminate in *ite*.

Besides this notation, another kind of chemical language is in use, the symbolical, which expresses the results of a process, and the changes which ensue, with a brevity unattainable in words, and by thus placing the reaction under the eye, enables the mind to grasp it more clearly and fully. The initial letter of the Latin name is used to signify one equivalent thereof, as in the following table:—

Oxygen,	O.	Tantalum,	Ta.
Hydrogen,	H.	Niobium,	Nb.
Carbon,	C.	Pelopium,	Pe.
Boron,	B.	Tungsten,	W.
Phosphorus,	P.	Molybdenum,	Mo.
Sulphur,	S.	Vanadium,	V.
Selenium,	Se.	Chromium,	Cr.
Iodine,	I.	Uranium,	U.
Bromine,	Br.	Manganese,	Mn.
Chlorine,	Cl.	Arsenic,	As.
Fluorine,	F.	Antimony,	Sb.
Nitrogen,	N.	Tellurium,	Te.
Potassium,	K.	Bismuth,	Bi.
Sodium,	Na.	Zinc,	Zn.
Lithium,	L.	Cadmium,	Cd.
Barium,	Ba.	Tin,	Sn.
Strontium,	Sr.	Lead,	Pb.
Calcium,	Ca.	Iron,	Fe.
Magnesium,	Mg.	Cobalt,	Co.
Lantanum,	La.	Nickel,	Ni.
Cerium,	Ce.	Copper,	Cu.
Didymium,	D.	Mercury,	Hg.
Yttrium,	Y.	Silver,	Ag.
Erbium,	E.	Gold,	Av.
Terbium,	Tr.	Platinum,	Pt.
Glucinum,	G.	Paladium,	Pd.
Aluminum,	Al.	Rhodium,	R.
Thorium,	Th.	Iridium,	Ir.
Zirconium,	Zr.	Osmium,	Os.
Silicium,	Si.	Ruthenium,	Ru.
Titanium,	Ti.		

To express a compound body, the symbols of its elements are placed side by side, as HO, water; H Cl, hydrochloric acid; KO, potash (oxide of potassium). If an element occur in a higher proportion, this is indicated by a number placed to its right, as SO^3, sulphuric acid (one equivalent of sulphur with three of oxygen). A figure placed to the left multiplies the entire group, as 2 CuO, two equivalents oxide of copper. When compounds of the first order unite among themselves, their symhols are connected by a comma, or by the sign +; as KO, SO^3 or KO + SO^3, sulphate of potash; KO + $2SO^3$, bisulphate of potash. Atoms of oxygen are sometimes expressed by dots placed above the other symhols. We strongly recommend all students of chemistry to make themselves perfectly acquainted with symbolical notation, without which the most valuahle works on the science cannot be understood.

We shall proceed, in the next chapter, to examine the most important combinations of the non-metallic elements.

THEORY AND PRACTICE OF DYEING.

CHAPTER XI.

MINERAL DYE-STUFFS.

In last chapter we described the salts of lead, and bichromate of potash, or chrome, which is used in connection with these substances, chiefly with the nitrate or acetate of lead, for the dyeing of yellows, oranges, and most kinds of greens upon cottons. We remarked, indeed, that these had completely superseded the use of vegetable dye-stuffs for such purposes. We now proceed to describe the preparation of another salt of potash, namely, the prussiate, which is used in connection with the salts of iron to produce the celebrated colour, known as prussian blue.

Prussiate of Potash. (Ferrocyanide of Potassium.)—We have on several occasions referred to compound substances which combine with bases, and in other respects act as simple bodies. Such substances are on these accounts termed *salt radicals.* One

of the most definite of these is cyanogen, which in its simple state is a gaseous body, and is composed of two of carbon and one of nitrogen. It does not exist in nature, but can be readily formed by bringing its elements together at a high temperature in contact with a base that will unite with it, and will remain in the compound state under the circumstances. Thus, when any organic substance containing nitrogen is calcined with potash, the nitrogen and carbon combine and form cyanogen which unites with the potassium of the potash, and forms cyanide of potassium. This is the condition in which it is generally obtained, and its union with other bases is effected by the decomposition of that compound; as, for instance, if we add a solution of cyanide of potassium to a solution of nitrate of silver, the potassium combines with the nitric acid and the cyanogen with the silver forming cyanide of silver, a dense white powder. When cyanogen combines with hydrogen, which it does with facility, it forms prussic or hydrocyanic acid.

Cyanogen is remarkable for combining with other elements and forming with them compounds which are also definite *salt radicals;* the principal of these is ferrocyanogen which is composed of three of cyanogen and one of iron. The compounds which this *salt radical* forms with other bases are distinguished by the prefix *ferro.* Thus, when united with potassium, it forms ferrocyanide of potassium (prussiate of potash) which is composed of one of ferrocyanogen and two of potassium. The prussiate of potash is prepared on the large scale by calcining together dried blood, hoofs, parings of horns, hides, old woollen rags, or similar material, with carbonate of potash, in an iron vessel; those substances are generally carbonised or burned in large cast-iron cylinders previously to being used with the potash. If the animal matters are used without being subjected to this process, they are mixed in the ratio of about 8 to 1 of pearl ash; but if burned, one and a half of the charcoal is mixed with one of pearl ash. When the animal matters are used without being charred, the calcining pot is left open to allow of the materials being stirred and the noxious vapours to escape; after which the vessel is closed, and the heat is increased. This is continued for some time, and at intervals of half an hour the mouth of the vessel is uncovered for the purpose of stirring the matter within. This process is continued until the flame ceases to rise from the surface, and the materials become a red semifluid mass, which generally takes place in about 8 hours after the pot is closed. The molten mass is scooped out with iron ladles, and allowed to cool. The theory of the formation of the yellow prussiate will be easily understood, on referring to what has been said of cyanide of potassium. The material of the iron pot in which the calcination is conducted, though sometimes iron filings are added for the purpose, combines with the cyanogen and forms the salt radical ferrocyanogen, which simultaneously combines with potassium, forming ferrocyanide of potassium. When the mass is cold it is dissolved in cold water, and the solution is filtered through cloth. Lest any cyanide of potassium should remain which had not received the proportion of iron, sulphate of iron (copperas) is added by degrees to the solution, so long as the prussian blue which is at first formed on adding the iron is redissolved. The whole is then evaporated to a proper consistency; after which, pieces of coarse cord are suspended throughout the liquid, upon which, as nuclei, crystals of ferroprussiate are formed in regular heaps. They are of a beautiful light citron yellow. From this salt all other ferrocyanides are derived as precipitates; those of the metals are formed by adding a salt of the metal to a solution of the prussiate. The following are the appearances of a few of those precipitates corresponding to the metals employed.

Protoxide of Manganese,	White, turning to a deep red
Peroxide of Manganese,	Greenish Grey.
Lead,	White with a yellowish hue.
Peroxide of Iron,	Deep blue.
Protoxide of Iron,	White, turning blue by exposure.
Copper,	Brown.
Zinc,	White.
Protoxide of Tin,	White.
Peroxide of Tin,	Yellow.

Each of these precipitates constitutes the ferrocyanide of the metal used, which has taken the place of the potassium; they are all insoluble in water, and where a colour can be obtained by them, they are suitable for a dye, although the colours dyed by the yellow prussiate are fugitive. Every alkaline substance, such as soap, destroys them, and they are easily affected by that universal destroyer of colours, the sun. The principal use of the ferrocyanide salt in the dyehouse, is for dyeing prussian blue. To dye this colour, the goods are impregnated with a persalt of iron, and then passed through a solution of prussiate of potash. Some cotton dyers are in the habit, when a dark blue is wanted, of putting the goods, after being tightly wrung from the iron solution, directly into the prussiate solution. We need hardly say this is waste of stuff, as it requires triple the quantity of prussiate which would otherwise do. Economy of stuffs is the primary object of all good dyers, not only on account of the expense, but from the fact also, that the more exact the proportion of his materials to the hue wanted, the finer and brighter is the colour obtained, and the less is the time expended upon it. When a dark shade of blue is wanted for yarn, the best method is to pass the yarn from the iron solution through a strong solution of potash or soda. Being washed well from this, it is put through the prussiate solution: this is the method adopted for dark blues, on printed calicoes; but for fine muslins, and such like, which require to be finished blue, this process does not answer so well, as the goods are generally coloured. Very little cotton yarn is dyed prussian blue, though an immense quantity of light piece goods are done so, requiring careful management to have them equal and all of one hue. In a former article upon mordants, we have described the method of preparing the solution of iron for the purpose of dyeing prussian blue, viz., to dissolve it in nitric acid. A little of this nitrate of iron is put into a vessel full of water, and well mixed. The cloth is put into this, and wrought as quickly as possible by the process of *edging:* that is, catching the edge of the piece with the right hand, and lifting it as high as the arm will allow, while the left hand is passed down along the edge, till the arms are at full stretch—the left hand retaining its hold of the piece, while the right hand lets it free, the piece spreads out full into the liquid. The left hand is then raised to meet the right, and transfers its hold to it, to go through the same operation. This is performed so rapidly, that a good edger will go round a 20 yard piece half a dozen times in a few minutes, so that the whole surface of the cloth gets equally exposed to the liquor. Being wrought from 10 to 15 minutes in this manner, in the iron solution, they are washed through two or three tubs full of clean cold water, which takes off all the superfluous acid and iron. Whether the cause of the reception of the dye be an attraction of the material of the cloth for the iron or the simple power of absorption of the fibres, we shall not stay to examine here; but although the nitrate of iron be an exceedingly soluble salt, the peroxide of iron remains fixed in the fibres, having abandoned its acid, and thus no washing will remove it. The cloth being well washed from the acid, it is put into the prussiate; but, as has been observed in a former paper, unless an acid be added to the prussiate, the goods, being washed and put in, receive no definite colour as the potassium which is in union with the ferrocyanogen, prevents it from combining with the iron. A small quantity of sulphuric acid is generally added to the ferrocyanide of potassium solution, to take up the potassium, and to set the ferrocyanogen at liberty to unite with the iron upon the cloth: this forms ferrocyanide of iron or prussian blue, and constitutes the dye. Considerable care ought to be taken in adding acid to the prussiate, otherwise the colour is liable to change, becoming grey or reddish when dried.

The following mode of adding sulphuric acid to the prussiate, when a considerable quantity of goods are to be dyed at once, is commonly practised. What is considered the proper quantity of yellow prussiate of potash is dissolved in just as much of boiling water as is necessary for solution. To this solution a quantity of sulphuric acid is added, so as to make it strongly acid. The mixture thus prepared is added to the *prussiate tub,* as may be required. This process for adding the sulphuric acid is exceedingly objectionable, as it causes the evolution of prussic acid, which may be detected by the pungent smell it excites. Now, in proportion to the escape of that gas will be the loss of the dyeing property of the prussiate. If three parts of acid be added to seven of yellow prussiate, the loss would amount to one half, while the remaining half would be so changed in its properties as to produce but a bad blue; thus the dyer must use an additional quantity of prussiate, and he produces but an indifferent colour.

The proper method of using the acid is to dissolve the prussiate in hot water, and to add the necessary quantity of this to the water-tub in which the goods are to be dyed; previously to putting in the cloth, a few drops of sulphuric acid are added, just sufficient to be perceptible to the taste, or, what is a much better test, sufficient to redden blue litmus paper. The goods being wrought for some time in this mixture, they are washed in clean water, having a small quantity of alum in solution. For light shades of sky-blue, they should not be dried from the alum solution, as there is a great tendency to assume a lavender hue. A better plan is to employ two tubs of water, the one being touched with alum, and the other pure for washing from it. Cloths dyed by the prussiate should be exposed to a very dry atmosphere when hung up to be dried.

In dyeing blues with yellow prussiate of potash, it is essential that the iron salt employed should be a persalt. Hence the reason that nitrate of iron, rather than sulphate, is used. If the iron be dissolved in sulphuric or muriatic acid, it would not yield a blue with yellow prussiate of potash; but if either of these solutions be raised to a boiling heat, and nitric acid added gradually till the red fumes cease to be given off, we would then obtain the persulphate, or permuriate of iron, and at a much less expense than the nitrate, besides being much better adapted for many light shades of prussiate blue; and, as we said in a former paper, far superior for dyeing lavenders, lilacs, &c., with safflower.

If a current of chlorine gas be passed through a strong solution of yellow prussiate of potash, till the solution changes to a reddish colour, and when a drop of it added to nitrate of iron gives no precipitate, there is formed chloride of potassium, and a salt differing materially from yellow prussiate. The solution being evaporated, this salt is obtained in beautiful ruby-red crystals, termed, from their colour, red prussiate of potash. This substance is well adapted for many operations in dyeing, but it is too expensive for general use. It yields the following colours with the salts of the different metals undernamed:—

Bismuth, ...	Pale yellow.
Cadmium, ...	Yellow.
Cobalt, ...	Dark-brown red.
Copper, ...	Yellowish-green.
Protosalt of iron, . .	Deep blue.
Persalts of iron, . .	No precipitate.
Manganese, . . .	Brown.
Mercury, ...	Red-brown.
Nickel, ...	Yellow-green.
Tin, ...	White.
Zinc, ...	Orange-yellow.

It will be observed by this table, that the salts of iron, which yield a blue with yellow prussiate of potash, give no colour with the red prussiate; and the protosalt of iron, which gives only a grey with yellow prussiate, yields a deep blue with red prussiate.

Yellow prussiate of potash is also used for dyeing shades of light brown with salts of copper. It is likewise much used for dyeing dark mazarines, and some other shades of blue, upon woollen, cotton, and velvet. By a very ingenious process of fixing a deep blue without any previous preparation of iron, it is principally used in calico-printing, and is effected by a mixture of yellow prussiate, sulphuric acid, and some of the vegetable acids, and salts of tin. The process for obtaining this beautiful colour upon velvets, has been but recently introduced, and is as yet not much known. It seems to depend upon the fixing of what is known as Everett's salt upon the goods. When an acid is added to prussiate of potash, the greater portion of the potassium is taken up by the acid, but there remains the iron and a part of the cyanogen, which unite and form a compound of two of cyanide of iron and one of cyanide of potassium. This salt is yellow, but rapidly absorbs oxygen, becomes green, and then passes into a deep blue colour.

Blue-stone, (sulphate of copper), is prepared from the sulphuret in the same way as sulphate of iron, the process for which has been already described in last volume. Its principal use in the dye-house is for dyeing Scheele's green. This colour is produced by boiling the cloth in a mixture of arsenious acid and sulphate of copper, then passing it through an alkaline ley, or more commonly lime water, and so on alternately. Superior processes might be had recourse to for producing the same colour; and indeed common humanity would dictate the complete abandonment of the process just described, as in several instances, the handling of goods dyed to this shade of green has terminated fatally. This fact ought to stimulate to further improvements in dyeing processes; and we think much might to this end be effected by the inducements which might be held out by moderate premiums, though we are sorry to say, that instead of receiving a premium, the workman is too often robbed of the honour of improvements which he does effect. The constant jealousy which exists amongst employers, will, we fear, prevent their joining together for the improvement of the general trade.

We have now described the principal substances used in the fancy dyehouse. We are aware that many points of minor importance have been omitted; but our general object has been to impress upon the operative the necessity of studying principles in conjunction with his practice, and we have therefore made our remarks as plain as possible. If we have been the means of inducing even one of our brethren to attend more particularly to the principles of his trade, we shall not consider that our labour has been altogether in vain.

LECTURES ON ARCHITECTURE.

By Professor Cockerell.

LECTURE III.

DOMESTIC AND VILLA ARCHITECTURE.

Of the divisions of the art proposed, that of Domestic and Villa Architecture alone remains to be considered. On this subject, two important preliminary remarks are to be made. Firstly—that the republican form of government, which prevailed in the ancient world after the 7th century, B. C. greatly influenced the style of domestic buildings, which were expressly unostentatious externally, towards narrow streets, lined with shops, reserving all their elegance for the interior, in the atrium impluviatum—porticatum—the exedræ, &c. Secondly—that populations and fashions having been derived from the East, an oriental character was impressed on the ancient habits and arrangements of countries in which (as in Italy especially) the northern and occidental now prevail, as derived from an opposite source. Whoever walks through the streets of Pompeii, after having resided amongst the Turks, will be struck with this fact. The profuse employment of water, in the bath, the impluvium, and in the corner of every street—the narrow streets—the secluded mansions, within high walls—the internal air and space—the subdivision of the house into the men's apartments and the women's—the harem—the lightness of the costume—all express migration from warmer climates, and a marked distinction of the races of modern and ancient inhabitants.

The Jews lived chiefly on the terraced tops of the houses, as the Pharaoh did. Ahaziah, king of Samaria, fell down through a lattice in his upper chamber, 2 Kings c. i. and it was thence that David, in a wanton moment, incurred the curse which fell upon his family. The house-top is ever the scene of prayer. "Let him that is on the house-top, not come down into his house, neither enter therein," (Mark xiii. 15); yet it is possible that in latter ages they had adopted the Greek and Roman ichnography,—it was, perhaps, through the roof of the atrium testudinatum that the sick man was let down to be cured, (Luke v. 19.)

The narrowness of the streets, and unostentatious style of the houses in Athens, occasioned disappointment to the traveller; in Rome the same; and as the houses were *limited* by the Augustan law to 70 feet high, we must suppose them unattractive. The fragments of the great plan of Rome, inscribed on the pavement of the temple of Romulus, by order of Septimius Severus, and published by Bellori, show the resemblance of the houses to those of Pompeii. It was an extraordinary innovation on the ancient humility of the Roman house, which Cæsar proposed, in demanding permission of the Senate to erect a pediment over his door.

But if the Roman nobles accomplished the admirable works described, in favour of the public, they did not neglect their own comforts. Under the empire they lived as individuals with the income of monarchs: and Strabo tells us expressly, that "they

built their villas after the palaces of the kings of Persia." The number of them was also extraordinary ; for, as Lucullus said, " they were as wise as those birds which change their residence with the seasons."

Cicero had nineteen villas, and it was in one of these that Cæsar honoured him with a morning call, and paid him the very high compliment of taking a vomit in order that he might do justice to his lunch. In another he delighted to ornament his library with Greek paintings and sculptures, which his friend Herodes Atticus was always collecting for him.

To the architect-antiquary Pliny has left a fortunate legacy, in the description of his villa at Laurentinum. It has often employed the ingenuity of the architect, since the revival, but with small profit, till the discovery of the ancient ichnography of Pompeii. (The Professor exhibited his own restoration, founded upon those data, in which, though he differed in some points from his accomplished friend, Mons. Haudebourt, in his elegant version of the Laurentinum, yet he strongly recommended it to the student, on account of the great research and taste shown in the composition. Some of the features he would describe.) You entered a small atrium, and thence a court in the form of the letter D, surrounded with a portico, which was enclosed partially with glass (the very original of our old conventual cloisters), and thus excluded rough weather. Thence through a gay court into a triclinium, which hung over the sea, and had windows all round three sides, giving the full enjoyment of the air, and view of wood and mountains beyond. To the left of this was a room, at the end of which was a rotunda (in apside curvatum), so contrived as to receive the sun's rays from the rising to the setting : in this was a case containing books, calculated to detain you, and such as " one loves to read over and over again." This arrangement afforded an angular parterre, protected on all sides except the south from the winds, and concentrating the sun's rays—a delightful refuge in the winter season. There were rooms heated by pipes from a hypocaustum, and others to retire to in stormy weather, to escape the roaring of the waves ; a large bath for cold and hot bathing ; a perfumery, and sphæristerium, or fives court ; a long gallery (crypto porticus) with windows on either side, which, when opened, admitted the fragrance of beds of violets, and the sun's rays at the rising and setting. " At the end of this," continues Pliny, " is a casino I built myself—my delight : in it I have an *Heliocaminus*, a sun chamber, warmed by windows all round ; while reposing on my couch in a recess adjoining, I can see the garden, the landscape, and the sea, through a *glazed door;* I can study in perfect quiet here, and escape all the noise and disturbance of my servants, occasioned by the Saturnalia."

The attention to the sun's rays in the milder climate of Italy, so conspicuously shown in Pliny's letters, is confirmed by all the authorities of antiquity. Vitruvius (b. 6, c. vii.) is very particular in his recommendations to this effect ; but the wisest of men, in a still warmer climate, has enforced this point yet more strikingly :—" To make a house pleasant," says Socrates, " it should be cool in summer and warm in winter : the building, therefore, which looks towards the south will best secure these objects, for the sun which will enter into the rooms in winter, will, by its greater altitude, pass over its roof in summer. For the same reason, these houses ought to be carried up to a considerable height, the better to admit the winter's sun ; whilst those to the north should be left much lower, as less exposed to the bleak winds from that quarter : for, in short," continues he, " that house is to be regarded as beautiful where a man may pass every season of the year pleasantly, and lodge whatever belongs to him in security." The modern Italians are not less attentive to aspect. But the most extraordinary villa of the ancient world, was that of Hadrian, at Tivoli, in which he displayed all the acquirements and collections of taste, during twenty-one years of constant travel through his vast empire ; in it was reproduced every remarkable building of the world, and probably every statue of celebrity, since from this magazine the Baths of Caracalla were furnished eighty years after, and the Vatican in some of its most precious ornaments. The whole was said to be enclosed in a wall ten miles in circumference. Pizzo Legorio, Kircher, Contini, and Panini, have engraved and written upon the remains.

The modern villas of Rome, built by the popes and cardinals since the fifteenth century, convey to us some of those graces in which the ancient villas abounded. In these, all the great masters of the revival have displayed their research and ingenuity. They are described in the elegant work of Messrs Percier and Fontaine, to which the Villa Pia, by Mons. Bloucher, has lately been added.

Our own architects of the sixteenth century encouraged by Bacon, Burleigh, and Wotton, certainly studied these works, and engrafted some of their principles on our Elizabethan Architecture, which adapts itself admirably to our climate and the extent of our establishments. Bacon (Essays, vol. I.) describes his idea of a villa with great detail, insisting upon the aspect and the seasons as primary considerations. Indeed, all authorities agree upon this subject, except those of the nineteenth century, and especially the patentees of hot air or hot water apparatus.

" The Elements of Architecture," by Sir Henry Wotton, are amongst the most precious and the earliest in our language. He was long ambassador at Venice, from Elizabeth and James, and seems to have been personally acquainted with Palladio. Domestic and Villa Architecture are special subjects with him ; for, says he, " Every man's proper mansion and home being the theater of his hospitalitie, the seat of self-fruition, the comfortablest part of his own life, the noblest part of his son's inheritance, a kind of private princedome, nay, to the possessor himself an epitome of the whole worlde, may well deserve by these attributes according to the degree of the master, to be decently and delightfully adorned."

In truth, during three centuries the cultivation of this branch of Architecture may be said to be peculiar to England, and that, while monumental and palatial edifices are better illustrated on the continent, the constitution of this country, and of the English mind—prone to the salutary retirements of home, the centre to which all its desires and warmest imaginings are ever pointing—have made the English house of every grade the most perfect in comfort and convenience, and the villa the beau ideal of individual possession, and the branch of the art in which our country excels beyond all others.

The compact square villa, after Palladio especially, was introduced by Inigo Jones, and much advanced by the model of those at Genoa, published by Rubens, who recommends them as full of beauty and convenience, and admirably suited to gentlemen of moderate fortune, such as the republic of Genoa is composed of. But the extension of the habits and the requirements of the present day have outgrown the square villa, and we are constrained to build a house beside the villa to accommodate them, with the worst possible effect in the group and in detail ; for in vain the plantation attempts to hide it out ; an anomalous composition is the result, and we had better have reverted to the Elizabethan mansion, which cast the house and offices into one in the extended E or H, or the French mansion, " entre cour et jardin," of the eighteenth century, reserving the centre for the best apartments, and the wings for offices, and the entrances in the angles communicating easily with all.

The least rational of English productions in this sort is seen in the castellated elevation adapted to this plan—the battlements and dungeon-keeps of Edward the Third upon the Italian villa of the sixteenth and seventeenth centuries. The menacing aspect, the machicolations, threatening hot lead upon the intruders, in the distance, are, on the approach, found to be peaceful and harmless ; the fortress is accessible at every window, and expresses a security from danger on better acquaintance, in direct contradiction to its fortified exterior. On entering the baronial hall, where you expect the paraphernalia of chivalry and the chase, retainers and bondsmen, you are addressed by a powdered footman, or may discover a housemaid sweeping the marble pavement.

The Grecian villa is hardly better conceived ; it may be taken for a library, or a philosophical institution. An extensive portico, borrowed from Minerva Polias, imposes its order on the whole composition, which is to be compressed accordingly, at the cost of all its internal proportions and accommodations. Every useful appendage of vulgar convenience is to be suppressed, as ill-suited to its Platonic refinement. As Swift says of Clelia,—

> " You'd think that so divine a creature
> Felt no necessities of nature."

But such architectural solecisms derogate from the dignity of the art, and convert into a theatrical or romantic dream, that which should imbody sound sense and rational invention.

The essential features should be prominently expressed ; the nobler portions, the offices, kitchen, the clock, and the stables.

should tell their own story. And fiction would be found unnecessary when all these are placed in due subordination and proper character by the artist's hand.

France, until recent times, essentially monarchical and aristocratic, has ever delighted in palaces; and since the reign of Francis I., they have been the most remarkable of Europe. In conception and design, and in many respects in execution also, the Louvre is the most magnificent palace of the world. Situated in the metropolis, and occupying thirty-two acres, its galleries and museums, and its gardens, form the recreation of the people. The paternal monarch invites them into his courts and vestibules, of which he esteems them the best ornaments, the most familiar and acceptable guests at all hours; participating with them his refinements and his delights, they are endeared and elevated, and the Palace of the Arts and Sciences, a part of the entire composition, and ranging in the axis of the first court, forming the chief object from its windows, assures them of the nobleness of his views for their honour and real advantage. The palace itself, the work of centuries, still unfinished, is the great atelier of artists,—the field in which they may exercise their genius for centuries to come in their several works,—the great harbour in which talent may find protection and employment.

The peculiarity of French orthography is in the high roofs, subdivided into pavilions, affording great effect in composition of various and cumulating forms, aided by their high chimney shafts and dormer windows, and their vast windows below them, suited to the northern climate. Indeed, Philibert de l'Orme, and the architects of his day, have rendered the Italian style homogeneous with the northern climate and circumstances in the happiest manner.

A military people delight in pavilions; each apartment was to represent a tent. So in the Tuileries the line of tents is terminated with two, distinguished by the name of Pavilions de Flore and Marsan. A maritime people delight in their ships: thus the English apartments convey the idea of "between decks," and the larger buildings are often like the man-of-war hulk laid up in ordinary. So in Russia the palaces have the air of barracks; vast and forlorn, they remind the spectator of the plains of Siberia. In Egypt, the Troglodite excavation was revealed in the temple palace; in Greece, the log-house in the temple structure: in China, still the tent, in its simplest form.

In the Middle Ages domestic architecture arose from the monastic structures in single rooms, lighted on either side like our colleges, the chimney shafts issuing from the eaves. The composite house of double rooms was borrowed from the Italians by Francis I., but even there the *dégagement* was wanting, and the chamber, ante-chamber, waiting-room, and guard-room, were all passage-rooms. It is in the English palaces that this problem has been best solved.

But this digression has led from the chronology of the art, which terminates with the Roman villa; and we now enter that melancholy period of history in which all ancient ideas of human enjoyment were absorbed in loftier and more serious aspirations. The art during the next 1000 years was employed alone in military and ecclesiastical buildings, by means of the Freemasons. The original institution of that order is traced even to the Greeks and Romans. Numa established the first corporations of architects, *(Collegia Fabrorum,)* together with the inferior college of builders, *(Collegia Artificum.)* They were invested with a religious character, and rights of framing laws and treaties amongst themselves. They greatly contributed to the increase of the Roman power amongst the barbarians, as have done our own people amongst the North American Indians, with whom an article of treaty, on their part, has always been to send a blacksmith amongst them. The Collegia were greatly promoted by the Roman Emperors in the rebuilding of cities, in the aqueducts and public works, and endowed with peculiar privileges, as freedom from taxation, holding councils with closed doors, &c. Victor relates that Hadrian was the first to attach a corps of architects to the Cohorts (about 120, A. D.)—an example which the admirable Institution of Civil Engineers at Putney, in favour of our Colonies, promises to follow with great advantage.

But it was at the termination of the eighth century, that the masons of Como assumed their peculiar form of Freemasonry, raised into importance by the patronage of the commercial and zealous Lombards, in the building of churches and monasteries with new materials; and dispersed after the destruction of that kingdom by Charlemagne, they spread themselves over Europe, obtaining bulls from the Pope, and maintaining peculiar rights and mysteries. Collegia had existed in England; but, destroyed by the ravages of the barbarians, the Freemasons (probably of Como) were invited by Alfred, and after by king Athelstan, who gave them a charter in York (926), the original of which is said to exist still in that ancient city.

In 1459 a grand lodge was erected at Ratisbon, of which the Architect of Strasbourg cathedral was the grand master. Charters and privileges were added by Maximilian, 1498. In 1717, Sir C. Wren was the grand master in England; but shortly after the ancient fraternity altered its original form and purpose, and became what we now understand by Freemasonry. Wren was then extremely old, and probably unequal to oppose the perversion which then took place; and which, from his known services to the craft, we cannot doubt was contrary to his wishes. Thus the period of the revival was arrived at, and it might be said that the problem of architectural power and combination had been worked out and solved, that the mastery of the ancients was admitted, and that such works would never again be performed; it would not again become a primary instrument of civilization. The human mind had passed through that stage of its discipline, and had embraced new sciences, engaging the faculties in occupations more advantageous to the improvement and happiness of our species. The intellectual growth to the manhood of our nature, now perhaps attained, would esteem Architecture ever a powerful engine in the attainment of the sublime and beautiful, but would probably never again indulge that preponderating regard given to it by the ancients.

The middle ages laboured after the ancient models with many divergencies: in the revival with the muses, the conviction of their pre-eminence was admitted, and their laws and principles were confessed as unalterable. Nothing then was wanted but to revive them, and the zeal with which this object was pursued was immense.

In 1416, Poggio Bracciolini, in searching for manuscripts, discovered a copy of Vitruvius, "covered with dust and rubbish, in a tower not fit to receive a malefactor," says he, "at the monastery of St Gal, at Constance." Copies of this happy revelation were spread amongst the learned, until the invention of printing, in 1445, multiplied them amongst the great architects of the day.—The magnificent Alberti was one of the chief of these, but not finding in Vitruvius sufficient to inform and fire the student's mind, he composed that work which all competent judges have esteemed the most masterly compilation in the art extant.

From that period to the present day we have a race of able architects in an uninterrupted chain, each adding some new grace or invention to the art on which their merit and celebrity are founded; all these we now appropriate without appreciating their difficulties, and without rendering due acknowledgment to each for the contributions gradually made to our common stock.

It must be premised, that the revival found the art under very different circumstances. The growth of liberty in the Middle Ages, magnifying the individual, whose house now became his castle, an aristocracy balancing the kingly authority, the increase of commerce, and many other causes, altered the whole face of domestic architecture; it might safely be asserted, that no palace of the solidity of the Strozzi or of Burlington House, ever existed in antiquity. The remains of the most insignificant temples and public buildings are still found; but the absence of any remains of such solid mansions as those throughout the ancient world might be adduced in proof that the domestic architecture of the ancients was slight and ephemeral. The houses of the ancients, like those of the Turks, were of wood and brick, covered with plaster and with paint. Columns indeed abounded, but they were moveables, or furniture, the objects of manufacture at the quarries, and of trade. These reflections are sufficient to show, that the features which the architects of the revival, in their endeavour to restore classical architecture, introduced, were new in execution and design, and required a stretch and effort of mind which we do not sufficiently take into account.

The first essays were in imitation of the system observed in the Colosseum and the Theatre, namely, the column and trabeation in relief, and superposed upon the frieze and arch; and this, on a small scale, formed a crowning order upon the tower on which Brunelleschi raised his dome at Florence. The same difficulties of constructing the trabeation, and of finding stone of sufficient size, and funds for opening the quarries, which had induced the decline of architecture under Diocletian, occurred on its restora

tion; and it required the experience of one hundred and fifty years to suspend the disengaged entablature in the ancient manner, with any boldness of scale and projection, as in Perrault's Louvre, about 12 feet 6 inches.

Brunelleschi, in his church of St Spirito and St Lorenzo, employed the orders in good proportion, but these supported arches. The celebrity of Bramante's St Pietro, in Montorio, doubtless arose in great measure from the accomplishment of the trabeated entablature, though the scale was indeed small, only 3 ft. 10 in. from column to column. But the timid application of the classical orders to the middle age buildings, often of large dimensions, gave them rather the character of trinkets hung upon them than of constituent parts of the fabric. Bramante, indeed, made a great step in the palace of Cardinal Wolsey, but the orders are still delicate in low relief, the windows circular-headed (from the difficulty of executing the square trabeated head) with the horizontal entablature above them. The basement, though elegant, has a gothic character, and the crowning cornice has but a small projection: the whole is dry and timid. But Bramante had the merit of inventing the coupled columns, which gave breadth and proportion to the front not otherways attainable. The ancients had left no examples of this disposition—but such were its advantages that it was at once accepted by Raphael and his successors: Perrault used it in the Louvre and Wren in St Paul's.

Alberti's bold and master mind originated many of those features which his successors knew how to adopt, particularly in his church at Mantua; he gave the hint which M. Angelo followed in St Peter's, of incorporating the whole height of the interior (not done till then) in one order, and vaulting the ceiling. His church at Rimini bears the stamp of Roman magnificence, quite beyond his age.

Peruzzi was the first to render his orders homogeneous with the structure, and his giving to the entablature of the upper order (especially in the Farnesina) a proportion suited to the entire height of the two, was as beautiful as it was new: it was afterwards adopted by Sansovino in the Library at Venice with the greatest effect.

This Peruzzi executed an entablature in the Palace Massimi. and square-headed doors of no mean dimensions (six feet six in ches between the capitals): but it was especially in perspective that he made advances far beyond the conception of his day. In other particulars, the merit of Peruzzi is unfolded by Serlio, his pupil, who possessed his collections, and published them through the patronage of Francis the First, in the first elementary work on the art written since the revival. The first edition in French is dated Paris, 1545; it was translated into Italian at Venice, 1550, and, by Robert Peake, into English, 1611, under James the First.

San Gallo was remarkable for the dignity which he gave to his buildings (especially the Palace Farnese), without the aid of the orders, except in subordinate dimensions, in the windows only, and in the interior court and vestibule. The verticality which is designed and usually conveyed by the orders, he communicated to his buildings by rustic quoins, which carry the eye up, and enable it to embrace the whole front. This invention, which appears to be wholly his own, became popular and universal.

The windows, with their small orders, are undoubtedly taken from the Roman tabernaculum, or ornamented niche, so often seen in the baths and in the Pantheon, and was also a new application.

Raphael, as great in Architecture as in Painting, adopted his master Bramante's invention of coupled columns, as also San Gallo's windows and quoins, and if he did not invent, he employed the balustrade with singular grace and effect,—for grace united with strength and nobility, his Palaces Pandolfini, Caffarelli, and Uggieri are unequalled; indeed, his letters show his enthusiasm for Architecture, his profound estimation of the antique, and his ardent aspiration for the restoration of Rome to its antique character and splendour. The backgrounds of his pictures are not less to be regarded as examples than his executed works, being designed with as much care as if they were to have been perpetuated in marble.

M. Angelo distinguished his designs by vastness and singularity, compared with the previous schemes of Raphael, Peruzzi, and San Gallo. We are surprised at his boldness in proposing one order, eight feet in diameter, for the external front, and a corresponding disengaged entablature for an extended portico in the west front—which latter, however, was never attempted. His palace of the capitol has many merits and peculiarities, one of which, practised in the Laurentian Library also, was the sinking his columns in niches.

Vignola has been deservedly regarded as a master of the first merit, and has been hitherto the great authority in the French school, as Palladio has been of the English. His stereotomy, profile, proportion, and composition, are admirable; his orders are generally subordinate, often at the top of his buildings—they are never coupled as in Bramante and Raphael, but he reconciles the wide intercolumniation by a panel which gives proportion and sustains the pilaster with excellent effect. This expedient, much followed in Italy and in France, was original with him, as was also his modillion cornice, extending to the frieze, and giving extent and importance to the entablature, proportioned to the whole height of the building, in a better mode than that of Peruzzi. This cornice was made the termination of the fabric, on which he never permitted a blocking or balustrade. But Vignola was chiefly remarkable for an artifice of composition, which, by subordinating the parts, gave apparent vastness to the whole; his doors and windows are remarkably small, the latter 3 feet 8 inches by 7 feet, only in Caprarola—but, being finely proportioned and complete in their members, deceive the spectator into the belief of actual scale. This artifice has been much used by his successors, especially in the upper portions of churches, with good effect, where no means of comparison or admeasurement are offered, just as a man becomes a giant when seen upon a hill and against the clouds.

Sansovino, the Lombardi, and San Michele, Palladio and Scammozzi, formed a school peculiar to Venice, uniting sculpture in the happiest manner with Architecture. In the Library of Venice, one of the most beautiful buildings of the world, Sansovino adopted two orders, to the upper of which he applied the deep frieze and entablature suited to the *entire* height, after the invention of Peruzzi, the intercolumniations being occupied with the Venetian window, so much employed afterwards in England. These windows having columns doubled transversely in the thickness of the wall, by which an amazing solidity and richness is communicated to the architecture; an arrangement subsequently adopted by Palladio in his town house at Vicenza with admirable effect.

San Michele, chiefly a military architect, and who first gave the gates of cities the character afterwards universal, is remarkable for the energy, richness, and expression, given to his works. His employment of the orders and of rustics is exemplary. His gates at Verona, and his palaces in Venice, especially of the Grimani, are masterpieces.

Palladio, by much the most laborious and learned architect of the revival, produced his effects by a happy employment of two orders, the one on a scale comprehending the entire height, the other subordinate, comprehending about two-thirds of that height. This principle had been employed by the ancients in the adjustment of side porticoes to the temple, and in the Propylea of Athens. In this last, the subordinate being 10, the principal is 15; in the Casa del Capitano it is 10 to $16\frac{1}{2}$; the same in the Basilica; in the Casa Valmarana 10 to $20\frac{1}{2}$. This principle may be regarded as the secret of Palladio's magnificence, just as the subordination of windows and features was of Vignola's. But his employment of the arch in conjunction with the trabeated arrangement adopted from the baths, his classical plans, his mastery over all the features and parts of architecture, cannot be enough studied.

The two volumes on the architecture of Venice, by Cicognara—the single volume of the works of San Michele at Verona, by Albertolli—and the works of Palladio, by Bertotti Scammozzi, should be within the reach of reference to the architect at all times.

The pompous Scammozzi (braggadocio, as Inigo Jones calls him, probably from personal acquaintance, in his visit in 1614), was a follower of Palladio, though he assumed to be an inventor. He was, however, the first to accomplish a portico, of any size, with a disengaged trabeation, in the church of the Theani. He was chiefly remarkable for the employment of orders above orders in well-studied proportions.

Galeazzo Alessi turned the peculiar locality of Genoa to immense advantage, and was the most active of those who have stamped upon the architecture of Genoa that sumptuous character so original and exemplary. This architect was in frequent competition with Palladio and Vignola.

L'Escot and Philibert de l'Orme, in France, laboured with great advantage on the materials thus offered by the great masters of Italy; and they are chiefly remarkable for their adaptation of their inventions to the requirements of a northern climate, in large windows, chimney shafts, high roofs, &c.

The student will add many more peculiarities and titles of merit to the great masters of the revival, from the hints here offered.

ORDERS OF ARCHITECTURE.

CHAPTER I.

The moderns have applied the term "order" to those architectural forms with which the ancient Greeks and Romans composed the exteriors of their temples. There are generally understood to be five orders of Architecture, namely: the Tuscan, the Doric, the Ionic, the Corinthian, and the Composite. The doric, the ionic, and the corinthian orders were originally designed by the Greeks, who knew nothing of the tuscan and the composite orders. The Romans borrowed the three Grecian orders, and modified them to suit their own purposes; and to these they added the tuscan and composite orders. The latter orders, however, have little claim to be separately classed, as they have much in common with the former three. The tuscan order, by its title, enables us to assign its origin to Tuscany, which is indeed the more certain by the fact that the Tuscans were originally a colony of Dorians. The composite order, as the name implies, is compounded from the other orders, and may be called in truth a corrupted Corinthian. The characteristics of an order are determined not so much by the ornaments with which it is embellished as by the essential proportions of its parts.

It appears then from this that there are three Grecian and five Roman orders; and the doric, ionic, and corinthian being common to both, they are distinguished as Grecian doric, Roman doric, and similarly for the ionic and corinthian.

The leading members of an order are: 1. A platform; 2. perpendicular supports; and 3. a lintelling or covering connecting the tops of the supports, and covering the edifice. The proportioning of these parts to the edifice and to each other, with the addition of suitable decorations, constitutes an *order* or *rule*. The principal member is the upright support or column, the accompanying members being subservient to this leading feature; the bottom of the column rests either on a general platform, or upon a particular square plinth. The lower part of the column resting upon the square plinth is usually encompassed with a selection of mouldings, which, from their position are, in conjunction with the plinth, termed the Base of the column. The upper end is likewise covered with a plinth, which, in conjunction with the accompanying mouldings on the upper end of the column, is termed the Capital of the column. The body of the column, or that part situated between the base and the capital, is called the Shaft. The lintelling or covering which lies upon the columns is denominated the Entablature, and is subdivided into three parts: the Architrave, Freize, and Cornice. The architrave represents a mere lintel, embracing the tops of the columns; the freize is intended to signify generally the ends of the cross-beams resting upon the lintels, having the spaces between them filled up, and having also a plain moulding to separate it from the architrave, and to conceal the horizontal joint formed by the two members; the upper member or cornice represents the projecting eaves of a Greek roof, showing the ends of the rafters. The whole is distinctly exemplified in the Grecian doric order.

Mouldings.—Before going into the details of the orders, it will be necessary to give an account of the various mouldings employed in Greek and Roman architecture. And, in the first place, mouldings may be defined to be prismatic or annular solids, formed by plane and curved surfaces, which are employed as ornaments, and are considered as forming constituent parts of an order. If we conceive a straight moulding to be cut through at right angles to its length, the section thus formed is termed its profile, and exhibits exactly its characteristic outline, from which its name is derived. Annular mouldings, again, or such as are formed upon a round surface, as the surface of a column, must be cut by a plane passing through the centre line or axis of the column, in order to exhibit their characteristic sections or profiles.*

* It is by some considered preposterous to lay down rules for the construction of contours, which are said to be subjected to no law of form except what is furnished by the individual's own taste. Seeing, however, that beautiful outlines may doubtless be traced by means of regular geometrical constructions, we think the insertion of the more common of these methods will be useful to those who cannot readily sketch for themselves.

A prevailing gracefulness of outline characterises the mouldings of the Grecian orders, which at once distinguishes them from the more unpretending and simpler mouldings of the Roman. Various modes are employed for describing the Roman, and more especially the Greek mouldings, so various are their applications and the modifications of form to which they are subject. The Roman mouldings, however, are usually composed of circular arcs. The Grecian mouldings exhibit every variety of conic section, elliptical, parabolical, and hyperbolical, the circle being seldom employed but in small cavettos and mouldings of contrary flexure.

The regular mouldings are eight in number, and are thus named: The Fillet or Band, the Torus, the Astragal or Bead, the Ovolo, the Cavetto, the Cyma recta, the Cyma reversa or Talon, and the Scotia.

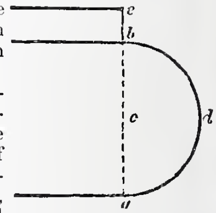
The Fillet *a*, Fig. 1, is the smallest rectangular member in any composition of mouldings. When it stands upon a flat surface its projection from the surface is generally made equal to its height. In general it is employed to separate other members.

Fig. 1.

In the following descriptions the extreme points of the curves are always assumed to be given.

The Torus and Astragal, shaped like ropes, are intended to bind and strengthen the parts to which they are applied. In form the Torus is a semicircle which projects from a vertical diameter. Thus, in Fig. 2, let *a b* be the vertical diameter, from which the torus projects; bisect, or divide in two equal parts, the line *a b*, at the point *c*; from *c* as a centre describe the semicircle *a d b*; this will be the profile of the torus, which, it will be noticed, is surmounted by a fillet *b e*. The astragal is described in the same way as the torus, the only distinction between them being that, when employed in the same order, the astragal is smaller than the torus. The torus is generally employed in the bases of columns; the astragal, both in bases and capitals.

Fig. 2.



The Ovolo is a member strong at the extremity, and obviously intended for support; it is usually employed above the eye as a supporter to the essential members of the composition. The Roman Ovolo consists of a quadrant or a less portion of a circle, and is described as in Fig. 3, the height and projection being given. And first, let the height be equal to the projection. Draw *a b* equal to the height, and *b c* at right angles with, and equal to, *a b*, for the projection. The quadrant, *a c*, described from the centre, *b*, with a radius, *b a* or *b c*, is the contour of the ovolo. But when the projection is less than the height, as in fig. 4, draw *a b* and *b c*, as before, at right angles, *a b* being the height, and *b c* the projection. From *a*, draw an arc of a circle, *b d*, with the radius, *a b*, and from the point, *c*, with the same radius, describe another arc cutting the former arc at *d*; the point, *a*, is the centre from which the ovolo is to be described, with the radius, *d a* or *d c*; this being done, the curve, *a c*, is the contour of the ovolo.

Fig. 3.

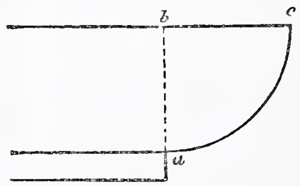


Fig. 4.

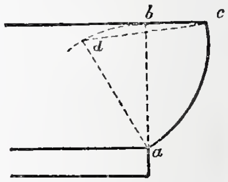
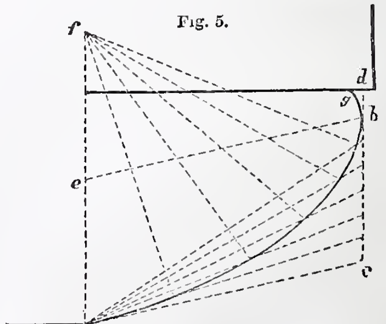


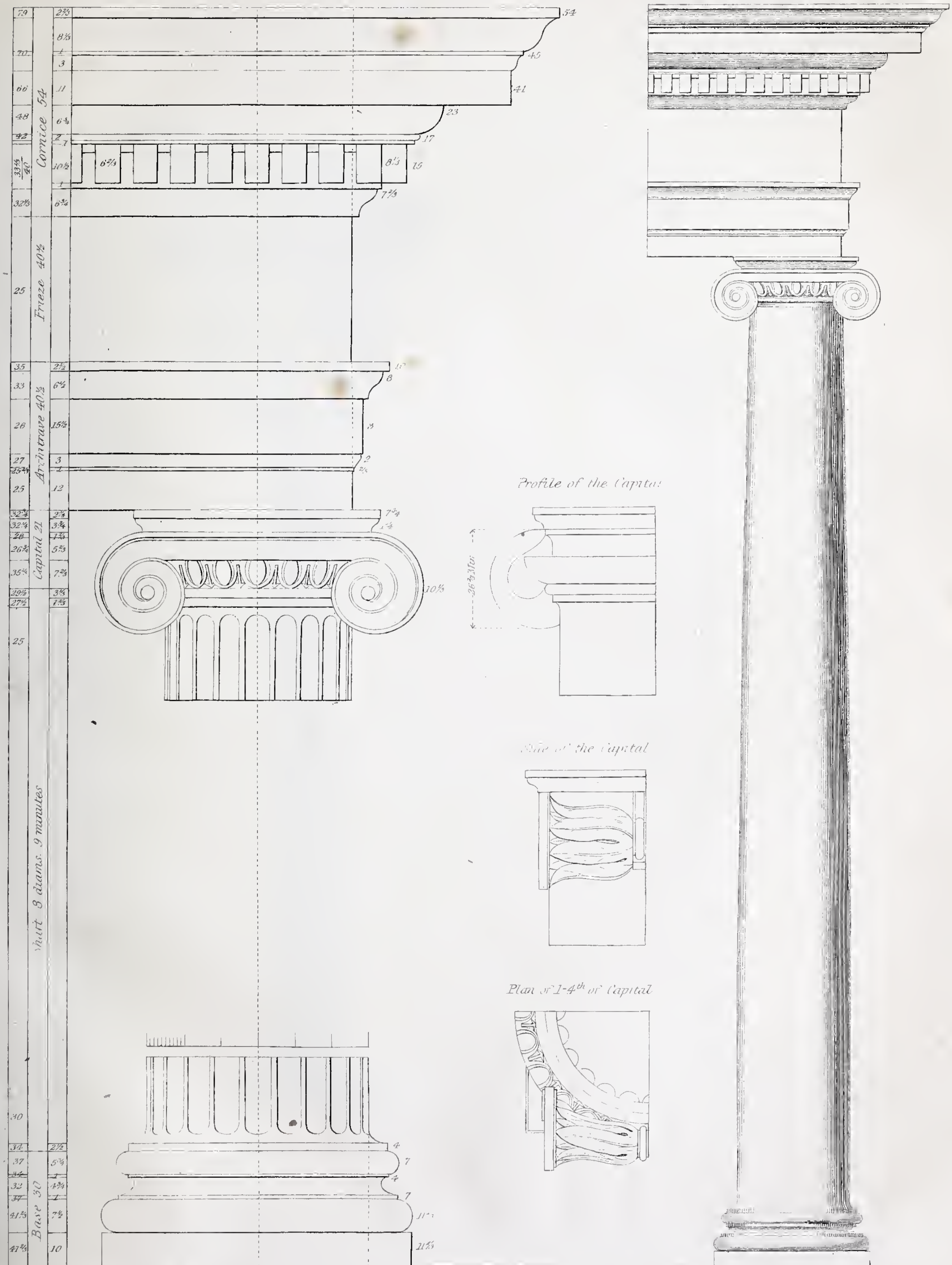
Fig. 5.



The Greek ovolo, fig. 5, unlike the Roman ovolo, cannot be de-

ORDERS OF ARCHITECTURE.

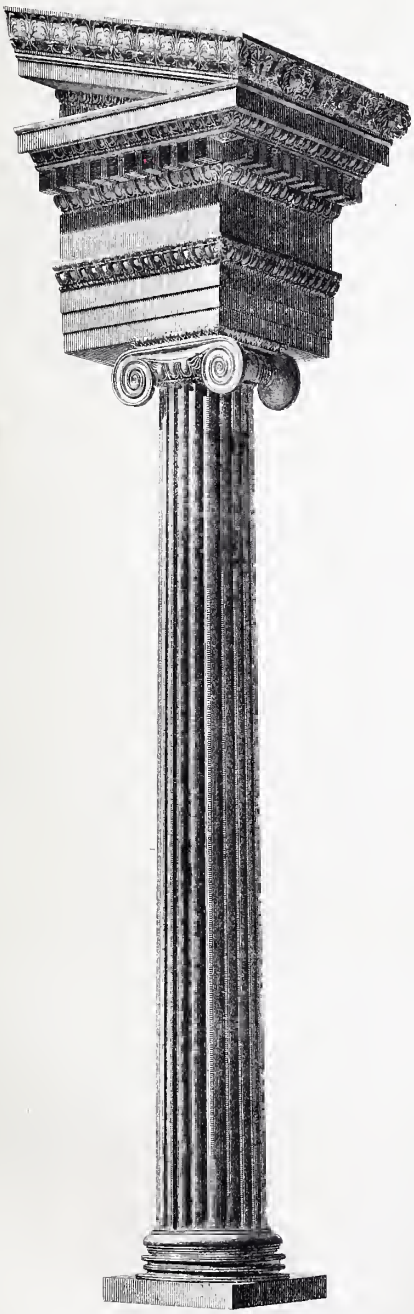
ROMAN IONIC ORDER.



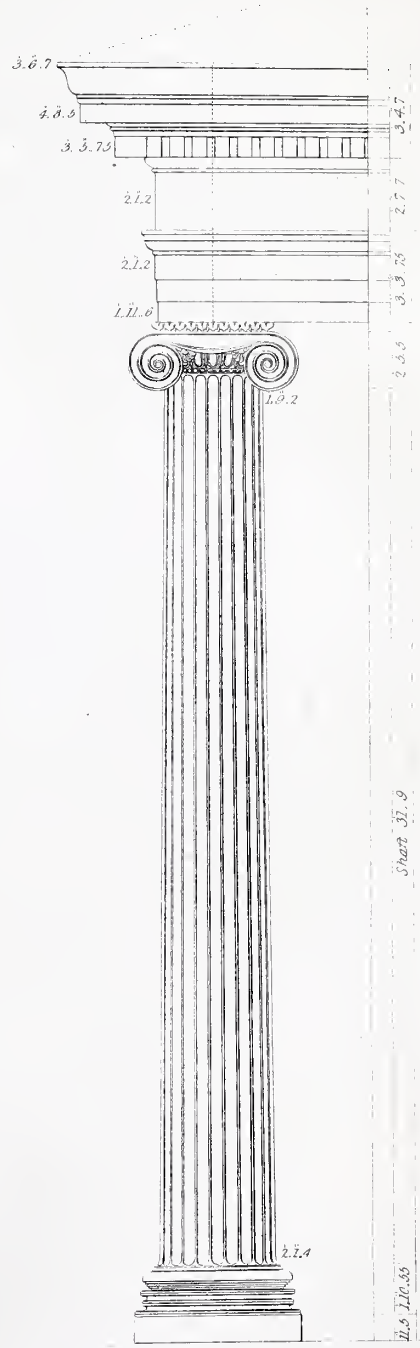
IONIC ORDER.

FROM THE TEMPLE OF MINERVA POLIAS AT PRIENE.

In Perspective.



Geometrical

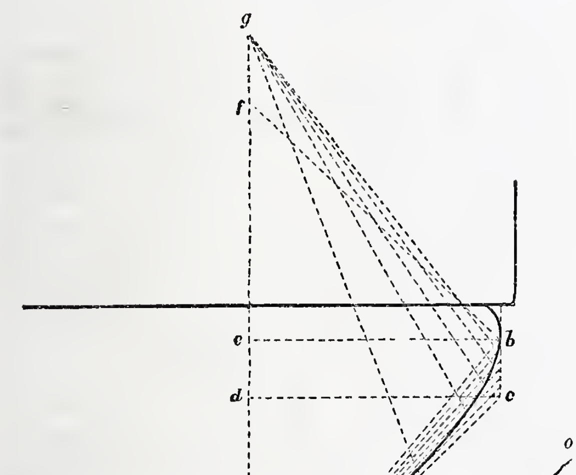


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 feet

scribed by means of circular arcs; it must be described by finding a number of points in it. For this purpose draw the tangent, *a c*, from the lower extremity, *a*, indicating the inclination of the curve at that point; draw also the vertical line, *d b c*, through the extreme point, *b*, or projection of the curve. Draw *b e* parallel to *c a*, and *a c f* parallel to *c b*; make *e f* equal to *a e*; divide the lines, *e b* and *b c*, into the same convenient number of equal parts; draw straight lines from the point *a* to the points of division in *b c*, and similarly, draw straight lines from the point *f*, through the points of division in *b e*, meeting successively the lines drawn from *a* to *b c*; the points of intersection of the pairs of lines thus drawn will be as many points in the contour of the moulding, and a curve line traced so as to embrace these points will be the greater part of the contour. The remaining part *b g*, if required to be determined in the same manner, may be found by drawing lines from *a* instead of *f*, through the points in *b e*, and from *f* to *b d*, instead of from *a* to *b c*. Of course this will give a good deal more of the curve than is necessary. The curve drawn in this manner is a portion of an ellipse, somewhat greater than a fourth of the whole circumference. The recess of the moulding, *b g d*, at its projecting point, is denominated a *quirck*. Fig. 5 is, from its great projection relatively to its height, adapted for capitals of Doric columns. With less projection, it would be suitable for entablatures.

To describe the hyperbolical ovolo (Fig. 6), as employed in Doric capitals—Having given the projection *b* of the curve and the lower extremity *a*, draw the line *a c* in the direction of the lower end of the curve, and *b c* vertically through the point *b*; draw *a g* vertically from *a*, and *b e* and *c d* perpendicular to *a g*; set off *e f* equal to *a d*, and *e g* equal to *a e*; join *b f*, and divide *b f* and *b c* into the same convenient number of equal parts; draw

Fig. 6.



straight lines from *a* to the points of division in *b c*, and also straight lines from *g* through the points in *f b*; the successive intersections of these lines, as in the foregoing case, are the positions of as many points in the contour. This is the general form of the ovolos in the capitals of the Grecian doric. It will be seen that the lower part towards *a* is nearly straight, and is succeeded by four fillets, shown in section on a large scale, and rounded away on the under sides into the fundamental line *n o*.

The Cavetto, (Figs. 7, 8, and 9,) which is the reverse of the ovolo, both in regard to form and to the weakness of the extreme parts, is well adapted for purposes of shelter for the other members. It is always employed as a finishing, and is here applied where strength is required. It is never used in bases or capitals, but frequently in entablatures; thus in the Roman doric order, it forms the crowning member of the cornice, and is evidently employed to overhang and shield the under members. The cavetto is described in the same way as the Roman ovolo—by arcs of circles, which may be either full quadrants or of less extent. The Greek cavetto (Fig. 9), is somewhat elliptical, and may be described by a combination of two circular arcs, thus: let *a b* be the projection of the moulding, and *a c* the vertical line; from the point *a* draw *b d* vertically from *b*, and make it equal to *b e*, which is two thirds of *b a*; from the centre *d* describe the arc *b i*; draw *i n* perpendicular to *e d*, make *n o* equal to *n i*, draw *o p* perpendicular to *a c*, and meeting *e d* produced in *p*, and from the centre *p* thus found, describe the arc *i o*. The contour *b i o c* will represent the Greek cavetto.

Fig. 7.

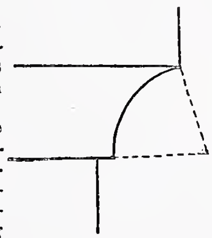


Fig. 8.

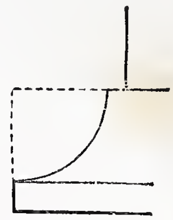
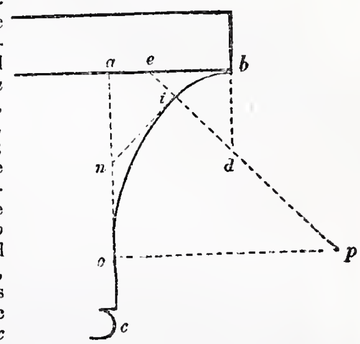


Fig. 9.



The Conge or Scape, (Figs. 10 and 11), is a species of cavetto, and is not recognised as a distinct moulding. In section it is partly concave and partly straight, the latter part being vertical.

Fig. 10.

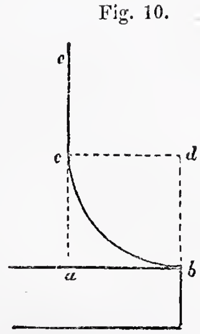
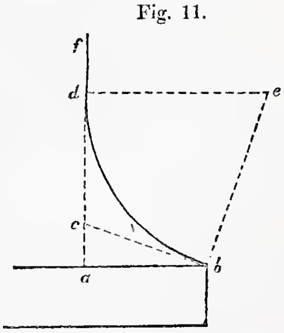


Fig. 11.



It is employed in the columns of some of the orders, for joining the capitals and bases to the shafts. Let *a b* be the projection of the moulding from the vertical line *a e*, which it is required to touch; and first, if the projection *a b* is equal to the height of the curve, make *a c* (fig. 10), equal to *a b*; and from the points *b* and *c* as centres, with *a b* or *a c* as a radius, describe the arcs intersecting at *d*; from *d*, with the same radius, describe the arc *b c*; this completes the contour of the conge. The centre *d* may likewise be found by drawing *b d* vertically, and making it equal to *a b*.

If the conge contains less than a quarter of a circle, as in fig. 11, let *b e* be the tangent to the curve at the point *b*; on the vertical *a f*, set off the distance *c d* equal to *c b*; draw *b e* at right angles to *b c*, and *d e* at right angles to *c d*; from the point *e*, as a centre,

describe the arc $b\,d$; this completes the contour of the moulding $b\,d\,f$.

These are the simple Roman forms of the conge. It is obvious that the curve may be varied into a combination of arcs of different radii, in the same way as the cavetto, (fig. 9,) which would render it more appropriate for Grecian profiles.

The Cymatium, or Ogee, is the term applied to a moulding of which the section is compounded of a concave and convex surface. There are two species of cymatium: the Cyma-recta or, simply, the Cyma, and the Cyma-reversa or Talon. The Roman Cymatium is usually composed of circular arcs, which may be either equal to or less than a fourth of a circumference. Thus, in the accompanying figures, 12 and 13, the former of which represents the Cyma-recta, and the latter the Talon, let a and b be the extremities of the curve; join $a\,b$ and bisect or divide it equally at the point c; from the points a and c as centres, with the same radius, describe arcs cutting at the point $e\ d$; likewise, from the points b and c as centres, with the same radius, describe arcs cutting at the point e; from the points d and e, thus found, as centres, describe the arcs $a\ c$ and $c\ b$; then the curve of double flexure, $a\,c\,b$, fig. 12, is the cyma-recta, and the curve $a\ c\ b$, fig. 13, is the cyma-reversa or talon. In the former, it will be observed, the concave portion of the surface is uppermost, whereas in the latter it is undermost. If the curve is required to be made quicker, a shorter radius than $a\ c$ or $c\ b$ must be used in describing the two parts of the contour.

Fig. 12.

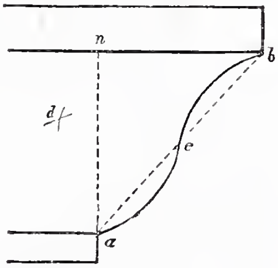
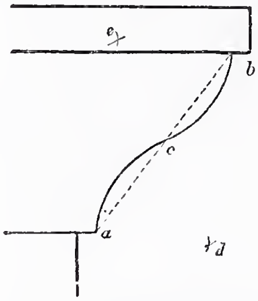


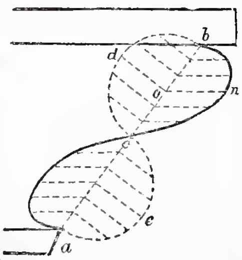
Fig. 13.



The projection of the upper end of the curve over the under, as $n\ b$, (fig. 12), is generally equal to the height $a\ n$ of the moulding.

The Greek Cyma-recta differs little from the Roman, except in that its projection over the under fillet is less than that of the latter, and that its curvature is also less. It may be described similarly to the Roman cyma (fig. 12) by means of circular arcs, described with radii of greater length than $a\ c$ or $c\ b$. The nature of the Greek cyma-reversa or talon is represented in fig. 14; the curvature of the moulding is much more deeply marked than that of the Roman talon. The concave portion $a\ e$ is deeply indented, and the convex portion $b\ n\ e$ projects considerably, and is *quirked* or turned inwards at b. The following is a simple mode of constructing the moulding, first introduced by Mr A. M. Nicholson:—join the points a, b, the extremities of the curve; bisect $a\,b$ at the point c; upon $b\ c$, as a diameter, describe the semicircle $c\,d\,b$, and on $a\ e$ describe the semicircle $a\ e\ c$; draw perpendiculars $d\ o$, and c, from any number of points in $b\ c$ and $c\ a$, meeting the circumferences of the semicircles; from the same points draw a series of horizontal lines, as represented in the figure, equal in length to the corresponding perpendiculars, $o\ n$ equal to $o\ d$, for example. The curve line, $b\ n\ e\ a$, traced through the extremities of the lines, will be the contour of the moulding.

Fig. 14.



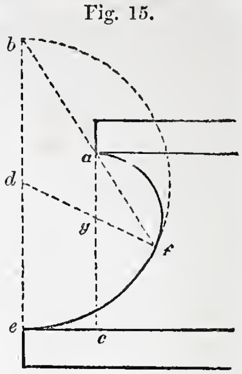
The curve might be rendered flatter by using arcs of circles of a diameter greater than $a\ c$ or $c\ b$, as, of course, the height $o\ d$ of the arcs would not be so great as it is in the figure; this will be exemplified in describing figure 17, which follows; also, if the upper part, $b\ n\ c$, be required to be larger than the under part, $c\ a$, of the contour, this may be effected by shifting the point c nearer to a, before drawing the circular arcs.

The cyma, like the cavetto, is always used as a finishing, and never applied when strength is required, as it is weak in the extreme parts, though it is applicable as a means of shelter to crowning members. The talon, on the contrary, strong towards its extremity, is, like the ovolo, well adapted for supporting weight.

The Scotia, fig. 15, like the fillet, is employed in bases to separate, contrast, and increase the effect of other mouldings, and conveys a graceful turn to the profile.

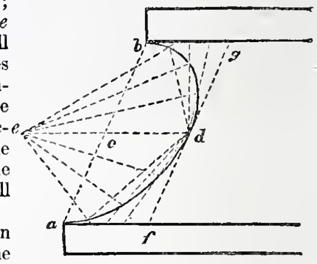
To describe the scotia, the extremities a and b of the moulding being given: draw the perpendicular $a\ c$, then $b\ c$ is the projection of the moulding; draw the perpendicular $b\ e$; add one-half of $a\ c$ and two-thirds of $b\ c$ into one length, which set off from b to d; from the centre d, with the radius $b\ d$, describe the semicircle $b\ f\ e$; join $e\ a$ and produce it to f; then join $d\ f$, cutting $a\ c$ in g; from g as a centre describe the arc $a\ f$; this arc, in conjunction with $b\ f$, completes the contour, $a\ f\ b$, of the scotia.

Fig. 15.



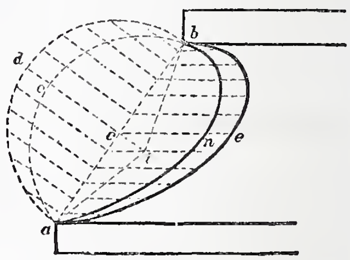
Another mode of describing the scotia is represented in fig. 16. Join the extremities a and b, and bisect $a\ b$ in c; draw $e\ c\ d$ horizontally, and make $c\ d$ equal to the required recess of the curve, and $c\ e$ equal to $c\ d$; draw $f\ d\ g$ parallel to $a\ b$; divide $a\ f$ and $a\ c$ into the same convenient number of equal parts, and to the points of division in $a\ f$ draw straight lines from d; draw also straight lines from e through the points in $a\ c$, till they meet successively the lines drawn to $a\ f$. Having performed the same operation on the upper side, the series of intersections thus found are points in the curve, and by tracing a line through them the contour will be completed.

Fig. 16.



In Fig. 17, a method is given in some respects similar to the preceding. Having joined $a\,b$, it describe upon the semicircle $a\,d\,b$; from the centre c, draw a series of lines perpendicularly from $a\ b$, meeting the circumference $a\ d\ b$; draw also a series of horizontal lines from the same points in $a\ b$, as shown in the figure, making these lines equal to the corresponding lines in the semicircle: $c\ e$ equal to $c\ d$, for example; the extremities of these lines will be as many points in the curve. If the recess of the curve is required to be less than $c\ c$, as, for instance, $c\ n$, then set off $c\ o$ equal to $c\ n$, and describe an arc $a\ o\ b$ from the centre i, which will be found after one or two trials; performing the same operation as in the other case, we find the contour $a\ n\ b$.

Fig. 17.



In comparing these three modes of describing scotias, it is to be remarked that the second is the most generally applicable, whether the recess and the projection be great or small, compared with the height. In the third mode, when the projection is small, the form of the curve approximates to that of the circular arc employed in describing it. Both of these modes of description are applicable to mouldings of any recess and projection. The mode first described, to produce graceful contours, should be confined to those of medium proportions, when, for example, the projection is two-fifths of the height, as in fig. 15.

The shaft of a column, like the mouldings which constitute the other portions of the column, may be described with various contours. The shaft is never cylindrical, that is, of equal diameter throughout; it is always tapered to a certain extent towards the upper end. The degree of taper is termed the diminution of the shaft; the diminution usually applied to columns ranges between one-fourth and one-sixth of the diameter at the bottom of the shaft. The following simple modes of diminishing the shaft of a column may be applied, when the diameter at the top and bottom are determined:—

Let the vertical line, A B, Plate I., Fig. 1, be the altitude of the column, and B C the half diminution at the upper end of the

shaft; divide A B into any number of equal parts, A a, a b, . . . and also B e into the same number of equal parts, B 1, 12, . . . draw the horizontal lines a f, b g, . . and draw other lines from the points 1, 2, . . slanting towards A, to meet the horizontal lines respectively at the points f, g, h, . . that is, the line drawn from 1 towards A, to meet the line a f at the point f, the line from 2 towards A, to meet b g at g, and so on; the points b, c, d, e, and f, thus found, will be points in the contour of the shaft, and by joining them into one bent line, A f g h i k e, this line will be the contour, or entasis, as it has been termed, of the column.

But suppose that less swell or bulging is to be given to the shaft; then, in fig. 2, divide A B, as before, into a number of equal parts, and B e into two equal parts at D; divide D C into as many equal parts as A B; then proceed, exactly as in fig. 1, to find the points f, g, h, i, k, in the contour. This will obviously bring the outline nearer to a straight line from A to B. In this figure, E F is supposed to be the axis or centre line of the column; E G and E A being the semi-diameters at the bottom, and F N, F e, the semi-diameters or radii at the top. To explain a third mode of determining the entasis of the shaft: on A G, as a chord, describe the circular arc A O G, proportionally less than a semicircle, as the swell is intended to be less; from the point N draw the vertical line N P, parallel, of course, to E F; divide the arc G P into any number of equal parts, G 1, 12, 23, . .; divide the altitude E F into the same number of equal parts; through the points of division draw the horizontal lines f l, s m, h n, . . . , and draw the vertical parallel lines, 1 l, 2 m, 3 n, . . . , meeting the others respectively at the points l, m, n, o, p; the curve line drawn through these points will be the entasis of the column.

In many instances the shafts of columns are not finished with plain round surfaces; their surfaces are frequently *fluted*, that is, indented by longitudinal flutes or grooves throughout the whole extent of the shaft. The flutes, when cut are applied entirely round the shaft, and their profile, which is shown by the section of the column, taken horizontally, is generally an arc of a circle, equal to or less than the semi-circumference.

There are two varieties of fluting represented in profile in figs. 3 and 6, Plate I., and shown also in elevation by figs. 4, 5, and 7, 10. In Figs. 6 and 7, it will be observed, that the flutes are regularly separated by fillets; while in figs. 3 and 4, no such intervention exists; the flutes meet each other edge to edge, and form a sharp angle or arris at their junction; the intervention of the fillets, as they strengthen the projecting angles, permits of the flutes being cut much deeper than when they follow each other consecutively. The circumferences of fluted columns are always measured, in the one case, over the exterior surfaces of the fillets, and, in the other, over the angles formed by the flutes.

To describe the flutes of a column without fillets: let A B, fig. 3, be the diameter of the shaft at the lower end; bisect A B at G, and describe the semicircle A E F B; draw A D and B e perpendicular to A B, and D e parallel to A B, touching the circle: draw also D E G and e F G to the centre; divide the semi-circumference into half as many equal parts as there are flutes in the whole circumference; more particularly, let there be twenty flutes in the circumference, then ten of these are due to the semicircle A E F B, and they ought to be so disposed as to have nine of them whole, and the tenth divided between the two extremities A and B, in order that a flute may stand directly in front, as seen in the figure, where the line D C touches the circle, To this end, then, divide the arc E F into five equal parts, and continue the division towards A and B, making two whole divisions and a half, as F d and d c, and c B. These points of division determine the arises of the flutes. To strike the form of the flute, describe arcs from the centres c and d, with the radius c d intersecting at e; from e, with the same radius, describe the concave surface c d; this forms the flute—the same process is applied to find the others. Having drawn the concentric semicircle a b for the diameter of the shaft at the upper end, if radial lines be drawn from the arises of the flutes in the circle A E F B towards the centre G, the points at which they meet the circle a b will be the arises of the fluting at the upper end of the shaft, which is described similarly to that at the bottom. The figure, as now completed, becomes a half plan of the shaft of the column. Fig 4 is a bottom elevation of the column, derived from the plan, as indicated by the dot lines; and fig. 5, is a top elevation.

To describe flutes with fillets in the shaft of a column: Let A B, Fig. 6, Plate I, be the diameter of the column; bisect it at G, and describe a semicircle, as before, upon the diameter A B; draw A D and B e perpendicular, and D C parallel to A B, touching the circle; join D G and e G. Let there be twenty-four flutes in the circumference; there will then be eleven whole and two half flutes in the semi-circumference, and five wholes and two halves in the quarter circumference. If, therefore, this space be divided into six equal parts, the points of division will be the centres from which the flutes are described, and, by running on the divisions to the points A and B, the centres for the whole semi-circumference will be ascertained, and will divide it into twelve equal arcs. Take any one of these arcs, F d, and divide it into five equal parts; then with two of these parts as a radius, from each of the aforesaid centres, describe a semicircle; this will be the section of the flute; the flutes of the interior circle, representing the upper diameter of the shaft, are found by drawing radial lines, which appears sufficiently obvious from the figure. Figs. 7, 8, and 9, are elevations of the bottom of the column, as found from the plan by means of the dot lines; fig. 9, represents the most usual mode of finishing the flutes at the bottom of the shaft; fig. 10, is the correspondin elevation of the upper end.

In describing by relative dimensions the proportions of each particular order of architecture, it is desirable, for the sake of perspicuity and facility of reference, that in all the orders one common standard of measurement should be adopted, to which the proportional dimensions of all the parts of each order should be referred, being expressed in parts of that standard. For this purpose, the diameter of the shaft of the column at the base in each order, is taken as the standard of reference for all the parts or members of the particular order. The advantage of this is twofold, for, first, the proportions of an order are seen by a few glances: and, secondly, the relative proportions of corresponding parts in different orders, are likewise readily ascertained. On this principle, we shall proceed in defining the orders separately. The diameter at the base in each order is divided into 60 equal parts, denominated seconds, and constituting the scale of parts for the particular order; this affords a ready means of accurately noting the proportions, which are expressed in seconds and fractions of seconds when these occur.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXV.

THE ORGAN OF HEARING (CONTINUED).—OF VISION: SECTION I., THE ANATOMY OF THE EYE.

In our last article we alluded to the practice of probing the eustachean tube in cases of obstruction, as well as of forcibly driving air into it with the view of removing the obstructions. Many accidents difficult of explanation have occurred from this practice, showing the necessity of caution in operating upon a part so near the brain.

In the cavity of the ear, called the tympanum, are placed the remarkable chain of small bones already spoken of. The uses of the cavity are not easily understood, and still less have physiologists been able to imagine what the functions of the chain of bones crossing the tympanum may be. Sonorous waves are propagated in the line of their original direction, regardless of all the inflexions of these bones; yet, generally speaking, when this cavity of the tympanum is diseased, hearing suffers. Matter collecting here gives rise to the most intense pain, until it find a vent somewhere.

It is now admitted that sonorous pulsations reach the labyrinth or inner ear in three different ways: 1st, by the chain of bones; 2d, through the osseous walls directly; 3d, across the tympanum, and therefore through the aerial medium found in it. Scarcely anything is known of the mode in which the auditory nerves themselves are affected by sounds. In the labyrinth there is a fluid or semi-fluid, or perhaps both, and probably through it the sonorous pulses reach the fibrils of the nerves. With a magnifying glass of ordinary powers, the nervous fibres of the ear may be well seen in the ear of fishes without any very troublesome dissection; but not of course the primitive fibrils, which require glasses of high power to be observed distinctly. In fishes also may be best observed those singular bodies termed otolithes, of extreme density, and an almost stony hardness in osseous fishes, soft and cretaceous in the cartilaginous kind, and in sharks and skate. These otolithes are represented in men merely by a few very fine crystals, and even these have neither been

well observed nor admitted by all observers. Thus the uses of the various parts of the internal ear or labyrinth is a great mystery. The primitive fibrils of each acoustic nerve has been calculated at 1200; now, every excitement, every concussion of these fibrils, gives rise to the sensation of sound, whether these be sonorous pulsations from without or not. Thus there are *subjective impressions* as well as *objective* sounds; that is, sensations caused altogether independent of an external world. The same, we have seen, holds in respect of the other organs of sense, and in that of sight especially.

In respect to musical sounds, individuals and races of men present the most striking differences. In all the races of men there are persons, and perhaps those very numerous, who have no musical ear whatever. Each race of men seems to have its peculiar music, just as they possess a peculiar form, physiognomy, mental and physical character, and language. No one accustomed to music could well mistake the music of the Russ or Sarmatian race for that of the Saxon or Celtic. What is called German music evidently partakes of two distinct characters, marking the distinct origins of the present races chiefly occupying Germany, viz., the Teutonian or Scandinavian, and the Goth, Hun, or Southern German. The pure Saxon race has no ear for music; hence England has not only no national music, but not even a national air. It would be extremely difficult to guess at the origin of the Italian music; and in respect to its being hard to the Greek, it may be remarked, that the modern Greek—at least it is asserted—has no musical ear. The extraordinary effects of *association* may best be understood by observing the enthusiasm with which the frightfully noisy and vulgar sea songs, and some others called national, as "Rule Britannia," "God Save the Queen," "British Grenadiers," &c., are received by audiences, who, being destitute of all musical ear, still imagine these wretched Scandinavian and Norwegian tunes to be melodious and musical. It has been said by some one, that Dibdin received a pension from George III. for destroying the public taste; but this was a mistake in one sense, seeing that no public taste existed. The Dutch are, in this respect, much as the English; they have not been able to compose a single air since they have existed as a people on the face of the earth. Nor will even the Celtic race, wherever found, have the musical ear and a national music; witness Ireland, Wales, and the Scottish Highlands.

Does double hearing ever occur like double vision? Some cases have been recorded, but they are exceedingly rare. We have no direct mode of judging of the *direction* or distance of sounds. Lastly, it would seem from the investigations of the ingenious Wollaston, that there are "sounds inaudible to certain ears;" the chirp of the grasshopper, for example, and the cry of the bat.

OF VISION.

SECTION I.—THE ANATOMY OF THE EYE.

It is universally admitted that the eye is an optical instrument of singular perfection; to understand, in so far as they can be understood, the functions of its several parts, requires a knowledge of the science of optics, together with an acquaintance with the structure of the eye itself. The human eye and its functions will chiefly engage our attention in the following brief remarks.

By means of this organ we not only are aware of the presence of light, but through it as a medium we take cognizance of the size, colour, position, and form of surrounding bodies.

With regard to the nature of light, two opinions are held by opticians. The one is, that its rays are composed of actual particles which radiate from luminous bodies; the other supposes the existence of a very subtle fluid, or ether, which extends over all space, and that the light consists in undulations or vibrations of it. The latter is probably the true theory; but the discussion of the merits of the two is uninteresting to the physiologist, inasmuch as the laws concerning the transmission of light are the same under both systems, and, moreover, are fortunately well understood. Some of these it is necessary to allude to.

When light passes through any single transparent body, as air or water, it always passes in straight lines; but when it passes from one transparent body to another, as from air to water for instance (except, indeed, when it falls perpendicularly upon the surfaces where they join), it undergoes a change of direction, or, to use the technical expression, is refracted. A familiar instance of this is seen by putting a cedar pencil into a tumbler of water, when, owing to this law, the part of the pencil under water will seem to form an angle with the part remaining above.

The degree of refraction varies in different bodies. We judge of it by supposing a perpendicular to be drawn to the surface of junction of the two transparent bodies, at the point where the ray of light quits the one and enters the other; and we observe whether its change of direction, in its course through the second body, be towards or from that perpendicular. If it be refracted towards the perpendicular, we say that the substance which it enters has the greater refractive power of the two. We find that, generally speaking, dense bodies have a greater refractive power than those which are rarer, as water or glass, for instance, than air.

When the surface which separates the two media is not flat, but either convex or concave, the direction of the rays of light which fall upon it is altered. Thus, in Plate II., fig. 2, *b b* is a convex piece of glass, and *a* is a luminous body, from which three rays are issuing. The central one, *a e*, falls upon the glass in a perpendicular direction to its surface at that point, and therefore passes on unchanged. But the ray, *a d*, on entering the surface, will be bent towards *e*, which is perpendicular to the surface of the lens at the point where *a d* enters; therefore, as glass has a greater refractive power than air, *a b* will pass on in the direction, *f*: in like manner, *a g* will be directed towards *i*. It is evident that, if these rays were prolonged, they would meet each other. The point of meeting is termed the focus.

On the other hand, the reverse would take place if the rays passed from a denser medium into one more rare. It is thus evident, that when a ray of light, passing through air, falls on a convex lens of glass (*i. e.* a piece of glass bounded upon each side by a segment of a sphere), or any other transparent medium denser than air, it will undergo two refractions—one when it enters the lens, and the other when it passes out; and it is farther obvious, that each refraction will bring it nearer to the axis of the lens.

If different rays, proceeding from the same object, pass through air, and fall upon a convex lens, the result of these two refractions will be to concentrate all these rays into a focus beyond the lens.

As a convex lens concentrates all the rays from a distant *point* into a focus, so it concentrates all the rays from a distant *object* into an *image*.

Now, the eye is essentially a convex lens, by means of which the rays of light, proceeding from an object, are concentrated behind it into an image, which, being placed upon the termination of the optic nerve, produces in the brain the sensation of sight. Nothing, perhaps, in nature presents so many beautiful contrivances for effecting this purpose as the eye does; and vision has always been considered to afford some of the best illustrations of Natural Theology.

The eye, or eyeball, situated deep in the orbit, is protected in front by the eyebrows and eyelids, and its surface is kept constantly moist by means of the secretion of the lachrymal gland, placed upon the outer side of the eye. The secretion from this is always oozing, and, passing over the eye, is carried into the nose through the little canal, the orifice of which is seen in the inner corner of the orbit. Mental emotion causes great increase of this secretion.

The eyeball is nearly spherical. It consists of membranes placed one within the other, and humours, or fluids, which these membranes contain. It is connected with the eyebrows by means of the conjunctiva, a mucous membrane, which, lining them, is reflected over the anterior part of the eyeball. The fig. 1, Plate II., represents a section of the globe of the

eye, &c. The sclerotic coat, or membrane, No. 1, is a firm fibrous membrane, and forms about four-fifths of the external investment of the eye. Posteriorly, it is penetrated by the optic nerve, 17. In front it is joined by the transparent cornea, 3, which is received within it after the fashion of a watch-glass: this is seen at 2. Just at the point of junction is a ring of light-grey matter, 4, called the ciliary ligament. The choroid membrane, 5, lies underneath the sclerotic, and is essentially a vascular structure, and terminates anteriorly in sixty or eighty little processes, called ciliary, 6. Underneath the choroid membrane is seen the retina, 7, which is nothing but the expanded termination of the optic nerve. Upon looking through the cornea, we behold a coloured circle: this is the iris, 8. This structure is muscular, and is perforated in the centre by an aperture well known by the name of pupil. By the contraction of the fibres of the iris, the size of the pupil can be changed, and is so changed according to the intensity of the light—being larger when there is little, and smaller when there is much glare. Of course, this is done independently of our will. The iris is suspended in a cavity, bounded in front by the cornea, and behind by the crystalline lens, 13. This is occupied by the aqueous humour. The space between the iris and the cornea is termed the anterior, 9, and that between the iris and the lens, the posterior chamber, 10. To speak exactly, the aqueous humour is in the anterior chamber, surrounded by a very thin membrane, 12, which secretes it. The lens is doubly convex, and perfectly transparent. Behind it is the vitreous humour, 15, which fills up the posterior two-thirds of the eye. It is surrounded by a thin membrane, which also forms a number of processes, projecting inwards, and dividing it into detached masses, 16, 16. Both the humours of the eye are almost entirely composed of water, containing only about 2 per cent. of animal and saline matter, while the lens contains 42 per cent.

The muscles of the eyeball are six in number, and, with one exception, originate at the back of the orbit, and are inserted into the sclerotic coat. These perform all the motions of the eye; and it is when one or more of them is contracted, that we have that form of squinting which can be relieved by an operation. The different motor nerves, arising from the brain and entering the eyeball, supply these muscles.

When the eye is turned towards any luminous body, whether it evolves light itself, as the sun, or reflects light, as almost all visible bodies do, the following phenomena take place. The ray of light which falls perpendicularly upon the centre of the cornea undergoes no refraction, but passes on through the transparent humours and lens to the retina. All other rays coming from the same object are refracted—first, when they enter the cornea and aqueous humour; then when they enter the lens, which has the greatest density and refractive power; and, lastly, when they pass from the lens to the vitreous humour. All these refractions are toward the axis of the eye, and hence all the rays meet about the same point of the retina where the ray which fell perpendicularly upon the cornea did. As before stated, as the rays from a point form a focus, so do those from an object, or set of objects, form an image or picture upon the retina, which gives us the sensation we call sight.

A little consideration will show that this image upon the retina must be inverted, or upside down. Plate II., fig. 3, represents two rays* issuing, one from each extremity of an arrow. These rays cross each other in the middle of the eye; those from *a* are brought to a focus at *b*, and those from *c* to one at *d*. In fact, if we examine the eye of an animal recently killed (for the coats and humours of the eye soon lose their transparency after death), the image can be seen upon the retina in the position we describe it. It is not easy to explain how it happens that we see the objects erect. It is not that the infant at first really sees everything the wrong way up, and learns his error by inference; inasmuch as in people, who, having been born blind, have obtained their vision at a mature age from an operation, no such thing has been felt, but they at once see objects erect. Some peculiar nervous arrangement, into which it is impossible to enter here, is probably the true explanation of this circumstance.

As the dissection of the fresh human eye is obtained with difficulty, and might even be unpleasant to many who may peruse this article, the writer recommends that in its stead the reader place before him the fresh eye of the sheep, removed from the head soon after death, and with a small knife, scissors, and forceps, he may, without the aid of any instruction, acquire such a knowledge of all the structures as will suffice for his understanding the functions of every individual part about to be spoken of. Let him commence with the back part of the mass coarsely removed from the orbit, and he will first observe the *optic nerve*, which has been cut across at the point where it passes from the orbit into the interior of the cranium, on its way to the brain, in which it terminates. If the dissector follows this nerve towards its other termination, viz., in the eye-ball, removing or cleaning and pushing aside the structures he meets with, he may probably observe, and ought to examine, the muscles connected with the eye-ball; all these muscles were connected with the osseous orbit before the eye was removed from the orbit; they are the four recti and the two obliqui muscles; which all commence or are attached at the bottom of the orbit, or around the entrance of the optic nerve into that cavity, with the exception of one, the obliquus inferior muscle. Tracing each of these muscles forward, he will find that they terminate by a thin tendinous expansion inserted or attached to the eye-ball. The uses of these muscles may be here stated generally to be, to move the eye-ball in every direction; to roll it about with the utmost facility, and to direct the axis of the eye-ball towards any object we propose attentively examining. In this way the axis of each eye is directed towards the same object, and the parallelism of both eyes maintained. All these muscles are supplied with nerves, viz., the 3d, 4th, and 6th, and some filaments from the 5th pairs, and no doubt also from the sympathetic system of nerves; the reason why so many distinct pairs of nerves proceed to the muscles of the orbit has never been explained, neither do we as yet rightly understand the functions or uses of these individual nerves and muscles.

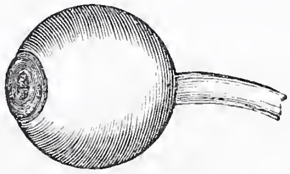
Let the reader proceed with his dissection, and cutting away or laying aside these six muscles, together with the elevator muscle of the upper eye-lid, which he may also have observed at the commencement of the dissection, and lying more superficial than the straight muscles, he will find a cushion of fat, with nerves passing through it in many directions. This cushion of fat has also its presumed uses; the eye-ball, as it were, rests upon it, or is pressed against it by the muscles already spoken of: and it is said that when from disease or want of a sufficiency of food, this cushion has been absorbed into the general system, producing a remarkable hollowness in the eyes, the animal will certainly die. However this may be, there is no doubt a state of extreme emaciation from which no animal can recover.

Having cleared away this cushion of fat, the reader will next observe a set of strong muscular fibres closely embracing the optic nerve, and attached all round and very firmly to the eye-ball. This layer of muscles is peculiar to the lower animals, not being present in man; he need not therefore regard it, but cut it freely away, and clear at once all the outer surface of the eye-ball, observing carefully the point where the optic nerve enters the globe of the eye. The part he ought next to examine is the strong nerve forming the exterior of all the back part and sides of the globe of the eye: a white fibrous tunic of very considerable strength. Into the fore part of this tunic, which is called the sclerotic, is inserted a circular and perfectly transparent convex plate, (the cornea), like a window. Through this transparent lamina the rays of light penetrate into the interior of the eye-ball; a fine membrane, also transparent, connects this plate or cornea and the eye-ball generally, to the eye-lids.

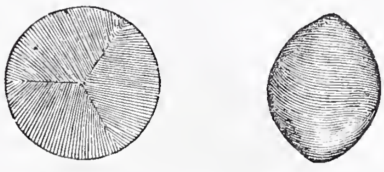
* We only give two to render the diagram clearer; but, of course, rays would proceed from all parts of the object.

By cutting into the tunica sclerotica, or outer fibrous protecting covering of the eye, the reader will perceive immediately subjacent a dark membrane covered outside and inside with a pigment. This membrane is the choroid; it is extremely vascular, and through it at the back part, as likewise through the sclerotica, the optic nerve passes into the interior of the eye. Let the dissector now remove a portion of the choroid with his scissars and forceps, and underneath he will find that layer of nervous matter called the *retina*, in immediate connection with the optic nerve, thought by some to be an expansion of it, and constituting the most important part of the organ of vision, for whose protection indeed all the other parts are formed. Before considering the uses of all these parts, let the reader proceed with his dissection, for without having first seen its structures, it is quite impossible for him rightly to comprehend any discussion on the uses of these structures.

If he now scrapes off a small portion of the layer called the retina, he will find that it is supported by a rounded very considerable mass, of a perfectly transparent substance like jelly or melted glass; hence called the vitreous humor, and more recently by De Blainville, the *vitrine* of the eye. This substance is enclosed in a membrane also perfectly transparent. Thus, passing through successive layers of membranes placed over each other, like the layers of an onion, the dissector arrives at the transparent humors filling up the interior of the eye-ball, and composing by far the greater part of it. These humors are three in number, viz., the aqueous, the chrystalline, and the vitreous. The best way to examine them is to make an opening into the transparent lamina called the cornea, whence the aqueous humor will immediately escape; its quantity and appearance may thus be estimated and understood—next cut away the whole of the cornea, and thus expose the moveable circular curtain called the iris; in the centre of the iris will be found an opening which is circular in man, but not quite so in the eye of the sheep. This opening is called the pupil of the eye, and is spoken of in common language as if it were a real existing body, whereas it is merely an opening in the iris. By passing a probe through the opening the dissector touches the capsule of the lens or chrystalline humor; now, to get a satisfactory view of the lens and vitreous humor, let him cut away all the tunics when these humors will be left on the table, connected together by their tunics, and freed from all other connections.



External view of the Eye-ball.



Two views of the lens or crystalline humour, prepared so as to show its singular fibrous laminated structure.

It were easy to have multiplied figures of the structures of the eye, but with no probability of enabling the reader to understand structures he has not looked at and handled. With a single remark, then, I shall close this section, intending in the next to examine more minutely, that is, in fact, physiologically, into the uses of all the structures here spoken of.

Whilst dissecting the eye of the sheep, ox, horse, or dog, or indeed of most quadrupeds, the dissector will observe, besides many other specialities peculiar to each species of animals, that a portion of the choroid towards the bottom of the eye, or its inner surface, has a bright metallic lustre; this appearance is called the Tapetum, and it is this which gives to the eyes of these animals the power of glaring in the dark, or when the most obscure light is present. Man has no such structure, and therefore his eyes never glare.

The lachrymal apparatus of the eye is shown in Plate II., fig. 5. We shall explain, in next section, the physiology of this organ, and some of the peculiar diseases to which it is liable.

DESCRIPTION OF A PORTABLE DIORAMA.

BY GEORGE TAIT, ESQ., ADVOCATE.

The diorama, the ingenious invention of the celebrated French artist Daguerre, is a painting, fitted up so as to receive light both in front and behind; by the full or partial admission, or the total exclusion, of either of which lights a great variety of effects may be produced. No light is admitted to the eye except that which proceeds from the painting.

The diorama is usually executed on an extensive surface of canvas, and placed in a large building fitted up for the purpose.

It occurred to Mr. Tait that it might be made upon a much smaller scale; and, accordingly, (before the publication of Daguerre's description,) that gentleman constructed, for the reception of sketches in water-colours which he painted for the purpose, a small box, having, for the admission of light before and behind, openings capable of being closed by moveable shades, and having also a small opening in front, through which the sketches might be viewed. Upon trying a variety of sketches in this apparatus, he found that many pleasing and striking effects might be produced: for example, passing gleams of sunshine; day melting into moonlight; day fading into darkness, followed by morning gradually disclosing the landscape, having its former verdure shrouded in snow. For this ingenious and elegant contrivance, Mr. Tait was honoured with the medal of the Scottish Society of Arts.

In Vol. I. p. 613, an account was given of a modification of the apparatus, by which the pictures, being placed in front of the box, were exposed uncovered, so as to be viewed by a number of persons at a time. This was a decided improvement on the first arrangement; but still there are certain advantages in point of striking effect attending the original form, which render it worthy of being described in detail, while taking occasion to present to the reader some of the inventor's observations on the management of the apparatus, the preparation of the pictures, and proper light to be used.

I.—THE BOX.

Stretching frames are to be prepared for receiving the paper or linen on which the pictures are to be executed; and as these are confined within the inner edges of them, the frames ought to be made thick and narrow, so as not unnecessarily to increase the width of the box, and should be bevilled off to allow access to the brush in painting the back. Those frames are inserted in succession through a slit in the top of the box, about two-thirds distant from the front, and are received into a groove projecting from the top, sides, and bottom of the box, of such a breadth as fully to cover the front of them.

Two openings, one above in front and the other behind, admit the light; and both should be as large as possible. The front opening ought to be of the form seen in the figure, in order to admit the light gradually; an erect right-angled triangle, with its base across the breadth of the box, being placed immediately behind the front opening to aid this object. The openings have a ply of fine tissue-paper, Persian silk, or other appropriate material, placed over them, to diffuse the light. This is moveable and is usually white, but may be of an orange, purple, blue, or other tint for particular purposes; and one or two plies may be used according to circumstances. The shades for the openings may be made to open and close in any manner found convenient, but so as to exclude all light when closed.

The small opening in the front, through which the pictures

are to be viewed, ought to be opposite to the ordinary height of the horizon of pictures, perhaps about a third or a fourth part of their whole height. A small tube, of about two inches in length, is fixed before that opening. The outer end is to be about an inch and a quarter in length, and about an inch in height, and is to be made to fit the eye, so as to screen it from extraneous light; while its inner end must expand into an oblong opening, so as to allow the spectator to view the entire picture. The tube may be made to receive lenses to magnify the pictures, if desired. The internal end of this tube must be so constructed as to prevent light from above shining into it.

The inside of the tube, and every part of the box seen through it, ought to be made as black as possible; for which purpose black velvet is very effectual. The rest of the inside, including the inner surface of the shades, ought to be white, in order to reflect light. The front of the box ought to be black outside, and surrounded by a black curtain.

It is necessary to have a small opening and tube, through which an exhibitor may view the pictures, when the spectator is unacquainted with the management of the apparatus. It should be on the same level as the spectator's tube. If the box be large, so as to admit of a distance of 8 or 9 inches from the spectator's tube, it may be on the front; if not, it will be necessary to have it on the side close by the front, and the pictures may be reflected to it by a very small mirror within the box. There should be placed over and behind it, to screen the eye of the exhibitor from the light without, a black moveable shade, which may be conveniently made of two parts, the upright part to support the horizontal part when in use, and both when not in use to fold upon the box. The part of the box within this shade is to be painted black.

The front and back shades should be fitted up in such a manner as to be opened conveniently, either by a spectator or by an exhibitor.

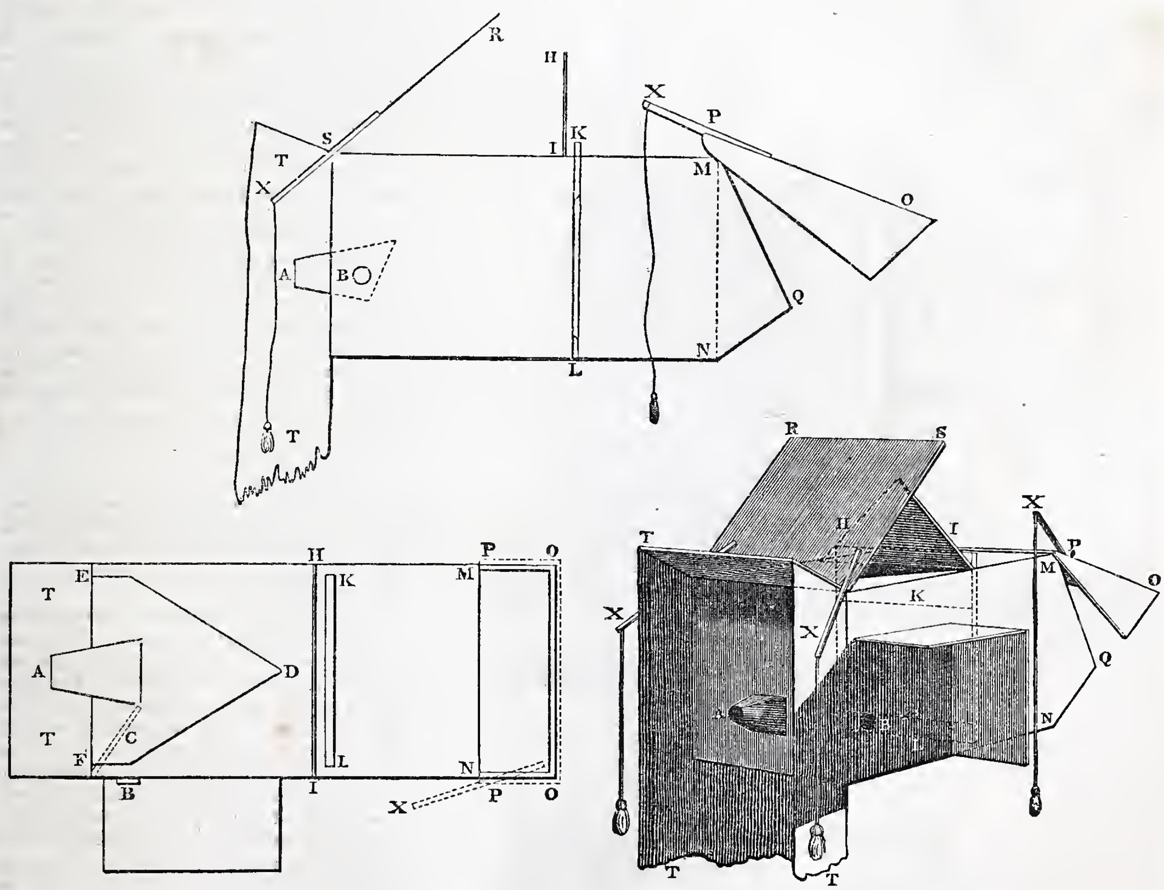
The box may be made of any size or proportions—the larger, the more striking the effect. And it may be supported upon a stand, or in any other manner convenient.

II.—THE PICTURES.

The pictures may be either in water-colours upon paper, stretched in the usual manner on the frames, or in oil upon linen.

In painting the front, whether in water-colours or in oil, the lights are left out, as in ordinary water-colour painting, so as to admit the light from behind to pass through; and body colours are to be avoided. The back of the pictures is covered with a strong semi-transparent tint, in those parts where it is wished that light shall not pass freely, or it may be

☞ *The subjoined figures show a side elevation, plan, and perspective view of the box. The letters of reference are the same in all the figures.*



A, Eye-hole for the spectator.
B, Ditto for the exhibitor, with a shade over it.
C, Small mirror reflecting the picture to the exhibitor.
D E F, Form of front light.
H I, Triangle to prevent a too sudden increase of light, on raising the shade, R S.
K L, Picture in its groove.
M Q N, Back light. The slope N Q is close. The slope M Q is open. It and the front light, D E F, are covered with tissue-paper or other appropriate material. The back-shade P O extends beyond the opening. The intention of this construction is to admit the light in a proper position, and very gradually.
T T, Curtain hung in front, to shade completely the light from the spectator.
X X X, Levers for raising the shades easily, with cords attached.

rendered opaque, if required. When painting the back, no light is to be used except that transmitted through the front.

Objects painted behind are, of course, not seen by the front light; and objects painted in front appear so faint when seen by transmitted light, that it is easy to paint the back in such a manner as to make them disappear when the back light only is admitted, by which means great changes may be produced.

For farther information with regard to the execution of the pictures, see Daguerre's description of his method of dioramic painting. There is an English translation of it by Dr. Memes.

The appearance of fog, which is not mentioned in Daguerre's description, is produced by painting the objects intended to be affected by it on a second surface, immediately behind the front surface. Light is admitted behind. When the second surface is removed more or less from the other, the objects on it appear more or less involved in fog; and, as it is brought into contact with the other, the fog appears to clear away.

A great variety of effects of daylight and moonlight may be produced by judicious management of the pictures, and by the adoption of contrivances sufficiently known or obvious to those who have paid any attention to art generally.

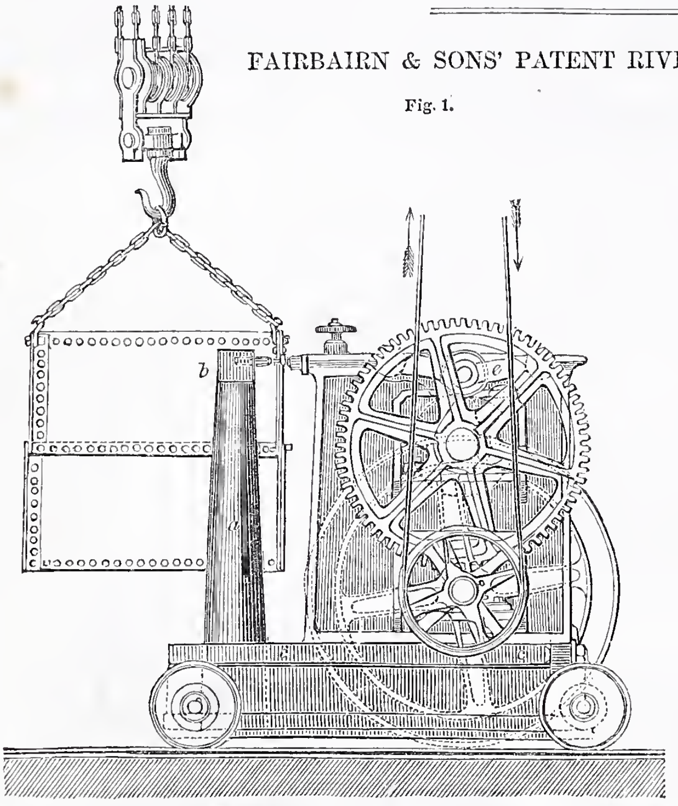
III.—THE LIGHT.

In daylight, the back of the box is placed close to a window, and no more light ought to be admitted into the apartment than is necessary fully to light the box. *At night*, the openings may be lighted with oil or gas, or even with a few candles, if the box be small. The very strong orange tinge of ordinary artificial light, is unfavourable to the natural and pleasing effect of the pictures; but it may be so far counteracted where necessary, as sometimes in night-scenes or snow-views, by interposing tissue-paper, or other appropriate material, tinted blue.

The effect produced depends in a great measure on the management of the light, and a few experiments will soon enable any one to regulate its admission, so as to exhibit every change of effect.

FAIRBAIRN & SONS' PATENT RIVETING MACHINE.

Fig. 1.



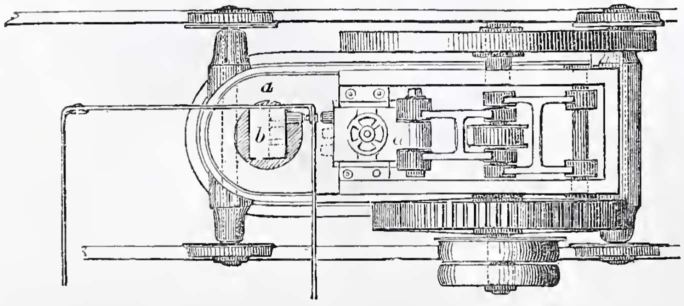


Fig. 2.

This machine for riveting boilers and other vessels, constructed of wrought-iron, was part of the magnificent collection of ingenious manufacturing mechanism which constituted Class 6 of the Great Exhibition in 1851. Like many other useful inventions, it originated in a turn-out of the boiler-makers in the employ of the exhibitors several years ago. On that occasion, necessity, the mother of invention, induced the making of an attempt to rivet two plates together by compressing the red-hot rivets in the ordinary punching-press. The result of the experiment was satisfactory, and immediately led to the construction of a machine, in which a moveable die was forced upon the rivet by a powerful lever, acted on by a cam. The machine which was originally constructed on this principle, although in some respects a great improvement on the old system, was soon found inadequate to the numerous requirements of the trade, and the improved form, of which the annexed sketches are given, was therefore adopted, and found to be of great efficiency. This machine operates, by an almost instantaneous pressure, what is performed in the ordinary mode by a long series of impacts; it performs twelve times the ordinary amount of work in a given time, besides the saving of one man's labour; the work produced is superior, and the riveting is done without noise, instead of the constant deafening clamour produced by the hammer of the workman.

Fig. 1 is a side elevation of this machine, and fig. 2 a plan of the same. The large stem, A, to which the immoveable dies are fixed at B, is made of malleable iron, and having an iron strap, C C, screwed round the base, it renders the whole perfectly safe, by slightly yielding to the pressure, in case of the dies coming in contact with a cold rivet, or any other hard substance, during the process. It has likewise a broad moving slide, D, in which are three dies corresponding with those in the wrought-iron stem. Every description of flat and circular work can be riveted by using the centre die; and by selecting those on the sides, the machine will rivet the corners, as shown in operation in the plan and elevation annexed. It can thus be made to complete vessels of almost every shape—to rivet angle-iron along the edges, and to finish the corners of boilers, tanks, and cisterns. The moving slide, D, supporting the

moveable dies, is worked by the action of a revolving cam upon an elbow-joint at E, which gives to the dies a variable motion, and causes the greatest force to be exerted at the proper time, namely, at the closing of the joint, and the finishing the head of the rivet.

The stem of the original machines was too low; but being now made 4 feet 6 inches high, it renders the machine more extensive in its application, and allows of its riveting the fire-box of a locomotive boiler, or any other work, within the given depth. It is likewise constructed in a portable form, and can be moved on rails to bring it to the different parts of the article suspended from the shears.

To give an idea of the work performed by this machine, it fixes in the firmest manner, and completes eight rivets of ¾-inch diameter in a minute, with the attendance of two men and two boys to the plates and rivets, whereas the average work that can be done by two riveters, with one "holder on," and a boy, is forty ¾-inch rivets per hour. The quantity done in the two cases is therefore as 40 to 480, or, as already stated, in the ratio of 1 to 12; and this, exclusive of the saving of one man's labour.

To give a particular case,—the cylinder of an ordinary locomotive engine boiler, 8 feet 6 inches in length, and 3 feet diameter, can be riveted, and the plates fitted completely by this machine in four hours, whilst to execute the same work by hand would require, with an additional man, twenty hours.

But the work is not only performed quicker, it is likewise acknowledged to be of a superior kind to that made in the ordinary manner, the rivets being found stronger, and the boilers more free from leakage, and more perfect in every respect. The comparative noiselessness of the process is likewise an advantage not to be overlooked, especially in crowded localities.

AGRICULTURE.

CHAPTER VIII.

THE MANAGEMENT OF A FARM DURING SPRING.

Spring is a busy time for the farmer. The two most important events that take place on a farm during this season, are the parturition of the various domesticated animals, and the sowing the seeds of some of the most important crops. Some of both these demand attention. We begin with the calving of cows.

CALVING OF COWS.

When cows approach their time of calving, care is taken that the litter in the court in which they are put to take their exercise is not too deep, as the exertion of walking over much loose and slippery matter is liable to produce miscarriage. Cows that have recently calved, are not allowed to go out at the same time with those soon expected to do so. The time when a cow should calve is marked down by the cattleman. He usually calculates it at nine calendar months from the time she was bulled, but he is almost always in error; the real time of gestation in the cow (although not quite uniformly) being 285 days, or five days more than ten lunar months. It is usually found necessary to diminish the allowance of turnips for a few weeks before calving, as cows, if in at all too good condition, are liable to various inflammatory affections at the time of parturition. Another great prediposing cause to such mischances is constipation; and this is avoided, either by giving purgatives, such as linseed oil, or by giving a daily small allowance of oil-cake with the food. Due care must, however, be taken, that the animal does not get in too low a condition.

The symptoms indicative of approaching parturition—as the enlargement of the udder, the coupling on each side of the rump bones becoming looser, &c.—begin to make their appearance about a couple of weeks, in general, before the calving takes place. When this last-mentioned coupling feels as if quite separated, the actual time of parturition is known to be at hand. It is not, as might have been expected, the cattleman, but the shepherd, who acts as accoucheur upon the occasion. The cattleman indeed attends to assist, and sometimes, for that matter, if it be night, do half-a-dozen ploughmen likewise. The proper procedure is, in all cases of natural labour, to leave the cow alone; but the assistants uniformly tie ropes to the unborn calf, and pull as if they were raising an anchor. Sometimes they pull the calf's head off, and sometimes they kill the mother; and whenever the calf is born alive, and the mother is not dead, they say that *that* calf never would have been born, if it had not been for their pulling. The management of the labour of a cow is one of the greatest disgraces of the farming of the districts, that, in describing the actual agricultural operations, &c., we keep in view. It arises, in part, from the farmer scarcely ever interfering upon such occasions, and from the shepherd, however valuable a servant in other respects, knowing nothing about the matter.

Should the cow, when the labour is over, appear much exhausted, she gets a drink of gruel, with a bottle of good ale in it, and she always, when her litter is adjusted, receives a quantity of warm water, with a few handfuls of meal stirred about in it. For two or three days her food consists of this drink, and mashes, very usually, of barley. Either oil-cake or oil should be given to her, to prevent any constipation.

The calf, as soon as born, is carried into the calf-house, and surrounded with plenty of litter, to keep it warm. The cow never sees it afterwards, and does not appear to care anything about the separation. It is proper, however, as soon as she is at all rested, to milk her.

The milk first drawn is very thick, and receives the name of biestings. This is given to the calf by hand. For the first three months, the calf gets as much milk, generally new milk, as it can consume. At the expiration of that time it learns to eat grass.

LAMBING OF EWES.

This is a very arduous and responsible season to the shepherd. When he knows that his ewes will begin to lamb, he is furnished usually with a grass paddock of one or two acres, or, if that is not convenient, a sheltered cover of a grass field of that size, fenced round with nets. He should also put in it a number of sheds, made with hurdles stuck against the hedge or wall, and lined and thatched with straw.

Into this paddock the shepherd drives the ewes that he is aware should lamb. He furnishes them with cut turnips, and carefully watches their proceedings. Most of them have their lambs born without any interference on his part, but sometimes he does interfere. Very often, after lambing, the ewe is sick, and will not, for a little time, pay any attention to her offspring. In this case the shepherd waits until the sickness is passing away, and then calls the notice of the mother to the lamb, by placing it at her head, for her to notice. If the ewe be not sick, she often attempts, as soon as the lamb is born, to bolt. The shepherd, in this case, stops her, and puts the tail of the lamb into her mouth. If the ewe continue to lie for some time upon her side, after having borne a lamb, it is because she is going to have another. The shepherd requires to attend to her, to take care lest she do not take to the second one, owing to her attention being engrossed with the first.

The lamb, at first, lies upon the ground, and the mother licks it. During this it makes great efforts to stand upon its legs. When it succeeds in doing so, we have a curious instance of instinct in it, and want of reasoning in the mother. The lamb darts at the teat to suck, and the ewe will persist in turning her head to keep licking it, thus removing the udder from the lamb. At length the lamb succeeds, and rewards its perseverance with a long drink.

Sometimes, however, the lamb cannot get hold of the teat without assistance. The shepherd, in such a case, turns the ewe upon her back, and taking the lamb in his hand, opens its mouth and applies it to a teat. Whenever the lamb has once sucked, the mother never forsakes it. When the ewes seem recovered, and they and the lambs have got well acquainted, they are driven out of the paddock and put into a new grass field. It is difficult to drive them, as the ewes will turn round upon and bewilder the lambs. The plan is to catch a lamb, and walk off with it. The mother soon follows

bleating, and owing to the habit that sheep always have of "following the leader," all the rest go quietly after.

Occasionally, the ewe will not allow the lamb to suck. The following plan is then fallen upon: she is put into the shed, and confined there by a short string, having one end fastened to one of her fore feet, above the fetlock joint, and the other to the hurdle. When the lamb then tries to suck, she makes off, but, of course, the string pulls her foot off the ground. While she is struggling with the string, and having her attention engaged by it, the lamb takes advantage of his opportunity, and catches hold of the teat. When this has been done once or twice, the repugnance of the mother ceases. In like manner the shepherd proceeds in the case of an orphan lamb, but is not always able to succeed. In this last case, and in the case of supernumerary lambs, bringing up by hand is the only resource left.

FARROWING OF SOWS.

The period of gestation in the sow is sixteen weeks, or a hundred and twelve days, although she sometimes exceeds this time by a day or two. The time when she ought to litter should always be marked down, in order that she may have the necessary attention paid to her. She may also be known to be going to farrow, and she will be seen carrying straw in her mouth, and making herself a bed in a corner of her stye.

The litter which is allowed to brood sows should be very scanty and short, and cut straw makes the best. The reason of this is, that the new-born pigs have a tendency to burrow among it, and so to get smothered or squeezed to death by their mother, from not seeing them, lying over them.

The average number of pigs born at a farrow, is, when the breed employed is a cross between the old native and the Chinese, &c., perhaps ten. A young sow at her first farrowing rarely attains this number, and older ones often exceed it. The first born pigs are generally the strongest, and the last born is almost always, and in large litters perhaps always, a weakly diminutive one, and is called by the country people, a poke-shaking, or wreckling. If the litter be numerous, this is generally put to death. The first born pigs generally take, and keep possession of, the foremost teats; and hence those that suck foremost are generally the biggest.

Luckily for her, the sow is apt to be rather savage if meddled with, and the country people are afraid to interfere very much with her when she is in labour. The consequence of this is, that scarcely ever anything goes wrong. She requires to be watched, lest she smother any of her pigs. When this is the case, it should be removed immediately, as sows have the disgusting habit of eating their dead offspring.

The sow, after labour, is generally exhausted and sick, and sometimes appears in a state of alarming fever, from which she soon recovers. It is proper to give her a good drink of warm gruel. The young pigs take to their feet as soon as they are born, and, true to their character of greediness, rush to a teat that very instant. But the sow has the power of preventing the flow of milk, and does so, until the whole number be born, and until she is rested. She then lies down, and every little pig works away at its teat. At first no milk flows, but by-and-by the sow makes a number of short grunts; the milk comes, the little pigs suck voraciously, and when they can suck no longer from excess of satiety, they often take their first sleep in this world with the teat in their mouths.

Unless the sow be both well and often fed while nursing, it is in vain to expect stout young pigs, and, moreover, she herself falls so low in condition, that it costs a great expense to bring her up again. A liberal allowance of some kind of meal, with boiled potatoes, administered at least thrice, but better four times a day, and always cooked, will more than recompense the trouble.

At six weeks the young pigs are weaned. Two or three of the strongest are removed one day, two or three more the next, and so on, until all are separated.

SOWING BEANS.

The proper season for sowing beans is February, as, if sown later, they are apt, at least in Scotland, not to come to full maturity. They are best adapted for heavy land. In some parts of England they are sown broadcast, and are sometimes taken after lea, and sometimes after a fallow crop. But in the districts to whose agricultural practices we always refer, they are invariably sown in drills, always on the fallow division, and the land is dunged. In practice, several little variations occur, but the following is, perhaps, the plan usually followed.

The piece of the fallow ground selected for beans, is the one which has first been ploughed in autumn, and in which the first dunghill has been made. Great judgment is required not to work the land, when it is in too wet or "raw" a state. The first operation is to grub the land with a Finlayson's harrow. This grubbing is best done across the ridges. The effect of it is to stir the ground very effectually, and yet to retain the upper part in its position, and thus preserve it dry, and prevent clods. After this operation has been performed, the land is harrowed along the ridges, and this must be repeated until the clods are well broken.

The land is set up in drills, 27 inches apart. In these the manure is deposited, being first put down by carts in little heaps, and then made to form a covering in the bottom and sides of the drill by the field-workers. A charged bean drill is then drawn by a horse along the drills, its spout being in the centre of the drill, just above the manure. A plough follows, and by turning over the land on the side of the drill, effectually covers it.

The quantity of beans employed for seed, is about five bushels to the acre.

Peas are sometimes sown along with beans, the stalks of the bean serving as stakes to support the creeping stems of the peas. The proportion of pea seed used varies, but is usually about a third. When peas and beans are so sown together, they are likewise reaped and thrashed together, and then separated by riddling, the peas passing through the meshes of the riddle, and the beans not.

SOWING SPRING WHEAT.

Formerly, when the price of wheat was much higher than it is now, to take it as often as possible was a matter of consequence. Accordingly, upon good land, sowing spring wheat came into custom, and as it is still continued, it is presumed to be found profitable.

With the exception of fern wheat, spring wheat is never sown later than March, and that, too, the beginning of March. It is usually grown after turnips that have been partly consumed by sheep, and it is found by experience that it will not answer, unless the land, besides having been well dunged for the turnips, is, and has been for some time, in good heart.

The land intended for spring wheat receives a single furrow. More ploughing would render it loose, and wheat never thrives save on firm land. The seed is usually pickled, with the view, probably an erroneous one, of protecting it from smut. Three modes of distributing the seed are practised. One is hand-sowing, and is now pretty much confined to small farms. As far as the picturesque is concerned this is a pity, for the steward, with his sheet, and firm and erect step, scattering the seeds, was a very pretty rural object. But, unluckily, hand-sowing requires about a bushel more seed per acre. Four or five bushels of wheat are required for seed when it is sown broadcast.

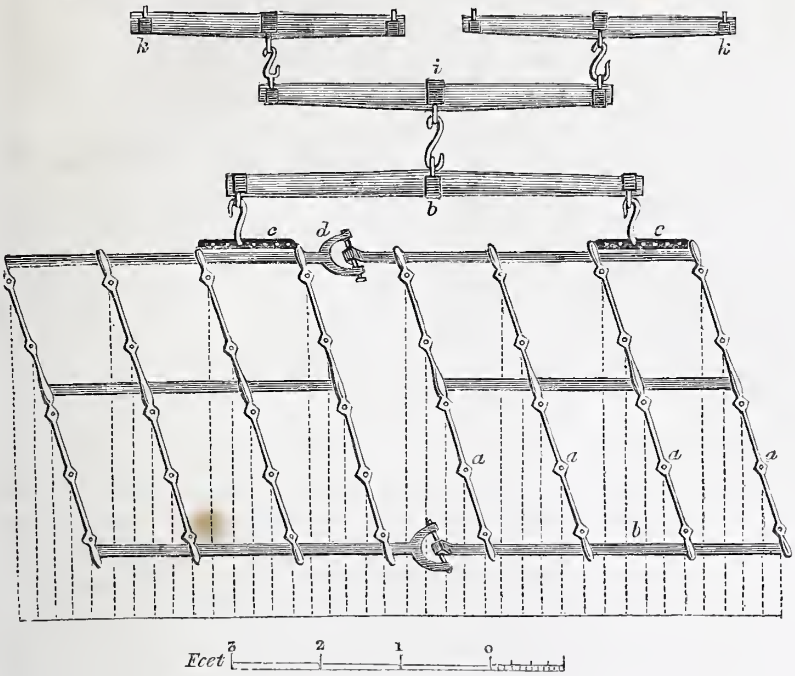
The broadcast sowing machine is much employed. It scatters the seeds upon the surface of the ground, in the same manner as the human hand; but it does it much more regularly, and therefore saves seed. It also sows grass seeds. It is used upon farms where the farmer does not choose to be at the expense of buying both grain-sowing and grass-sowing machines.

The drill-sowing machine is the best of any, inasmuch as it deposits the seeds in rows at any breadth, and also at any depth, the farmer pleases. It will not, however, as just observed, sow grass seeds.

After the sowing, whether by hand or machine, the seed is covered by the harrowing of the land. Harrows are now usually constructed of iron, and made, not as they used to be in a rectangular, but in a rhomboidal shape. In order to make

the harrows work well, it is necessary to make the horses keep a pretty quick pace. Three or more harrowings are necessary to cover the seed with a fine mould.

After the harrowing, it is usual in wheat, and also in other early corn fields, to make water furrows or channels, by which



the water may flow off the surface of the land. This is usually done by the common plough pulled by one horse, or by the double mould-board plough, also drawn by one.

SOWING OATS.

In the red sandstone districts of Scotland, the lea-land is invariably sown with oats, and so adapted, or so well understood is the culture of this cereal in these localities, that it actually often produces a greater return in money than wheat does.

The lea-land is last ploughed of those fields that are ploughed. If it have been ploughed for some little time, and especially if after one year's grass only, the furrow slices lie close enough together; but if it have been recently ploughed, or after old grass, or in heavy clay-land, the furrow slices are apt to lie pretty far asunder. The consequence of this latter is, that some of the seed, when thrown upon it, falls seven or eight inches below the surface, and by consequence never germinates. Upon such land, it is usual, before sowing the seed, to harrow; and indeed the custom of harrowing lea before sowing oats, seems of late to have been in all cases becoming general.

The quantity of oat seed sown is from five to six bushels per acre, and it is of importance that the ploughed lea ground on which oats are sown, should be dry when this operation is performed.

After the seed is sown, the land is well harrowed, both along the ridges and across them. It is necessary, as lea-land is often bound together in small clods, to have the lines of the harrows very sharp.

Oats are sown by hand and a broadcast sowing machine, and sometimes, but much less frequently, by a drilling machine. Indeed, on hard ground, where the grass has been for two or three years, the drilling machine acts very imperfectly.

After the sowing and harrowing, the fields are water-furrowed.

The usual time for sowing oats in the Lothians, is about the middle of March.

SOWING BARLEY.

After the oats are sown, the next important field labour is the preparation of the land for the barley crop. The land selected for this purpose is always turnip land, upon which, in general — and indeed upon mixed husbandry farms always—sheep have been fed. Wheat, we have seen, requires a firm dense soil—oats in this respect are more independent—but barley only thrives upon a very well-pulverized one. To produee such a condition of the soil is the object of the farmer intending to cultivate barley.

The first thing that he does, is to give the land a double harrowing, for the purpose of breaking clods. It is then twice ploughed, and usually cross-ploughed. After this a seed-land is formed, either by the grubber, or the small ribbing plough. In the former case, the barley is, if the implement exist upon the farm, preferably drilled; if the latter, it is either sown broadcast, or by a broadcast sowing machine. The quantity sown is about three or from that to four bushels per acre, and although the earlier the process be done the better, the sowing of barley may be deferred until even the end of May.

Of course, after the barley seed has been sown, the land is harrowed.

SOWING GRASS SEEDS.

In the language of the farmer, grass seeds, mean rye-grass, Italian rye-grass, red-clover, white-clover, and yellow-clover seeds. Of these the Italian rye-grass, which is not very much cultivated, although perhaps it ought to be so, is sometimes sown by itself, but the rest are always—save for some exceptional purpose—sown amongst a cereal crop. The cereal crop that is most adapted for this purpose is barley, but necessity compels the farmer to sow them likewise among wheat. Upon the farm to which we all along make particular reference, grass seeds are never sown amongst oats; but as upon some farms, where the convertible husbandry is followed, oats are the only cereal crop grown; the farmer is compelled to sow them amongst it.

Where grass seeds are sown amongst barley, the operation is performed immediately after the harrowing of the barley seed. Amongst autumn sown wheat they are usually sown somewhat earlier than amongst barley.

The proportion in which the different seeds are mixed, are varied according to circumstances. One bushel of rye-grass per acre, is sufficient to form the basis. Many are of opinion that the half of this is better substituted with Italian rye-grass, and we are inclined to think they are right. If the grasses are intended to last only one year, ten pounds of red-clover and two of white—in this case of doubtful utility—are commonly employed. When longer than one year, about six pounds of red are used and four of white. To these are often added two pounds of yellow-clover seed. This yellow-clover, we should observe, is no clover at all, but a species of lucern, and, as far as we can perceive, a mere weed. Its apparent cheapness seems to have caused its adoption. Timothy-grass is often recommended to be added to this mixture, but is very rarely done so. It is advised, that several other grasses should also form a constituent in the mixture; but in practice this is never done.

Upon small farms these grass seeds are sown by hand, and upon large ones, either by the corn broadcast-sowing machine, or by a special grass-sowing machine. After the grass seeds are sown, they are covered by the ground being harrowed by very light harrows—grass-seed harrows made for the purpose.

PLANTING POTATOES.

The potatoes are taken on the fallow land, *i.e.* stubble land ploughed in autumn. A dunghill will also have been conveyed to the field destined for potatoes; and if the farmer have been beforehand with his work, he will have had it cross-ploughed, harrowed, and thoroughly cleared before the month of April, which is the proper time for committing the potato seed—it is always called *seed*, although a tuber—to the ground.

Potatoes are sometimes planted whole for seed; but as this entails much and apparently quite unnecessary extra expense, the usual plan is to divide each tuber into sets, each set containing an eye. This is done by the field-workers.

The ploughmen then set up the land in drills, split them, lead on the dung, which is spread in the drills by the field-workers—who then place in, by hand, the sets at the distance of from nine to twelve inches—(the drills are twenty-seven inches apart). The ploughs then follow, and cover in the drills.

The quantity of dung necessary to raise an abundant potato crop is very great. Of late years, owing to the potato disease, they have been a very precarious crop. With regard to the real nature of this potato disease, nothing satisfactory is known. But, indeed, the same remark may be made with truth, with regard to all diseases affecting vegetables.

HORSE FEEDING.

At the beginning of seed-time, horses begin to receive hay in place of straw. This is partly because the bean and wheat straw are getting done, but principally because hay is much more nutritious, and the time is coming when the horses are beginning to work very hard, and require to be kept in good condition.

ASTRONOMY.

CHAPTER VI.

UNIVERSAL GRAVITATION APPLIED TO THE EXPLANATION OF THE MECHANISM OF THE HEAVENS.

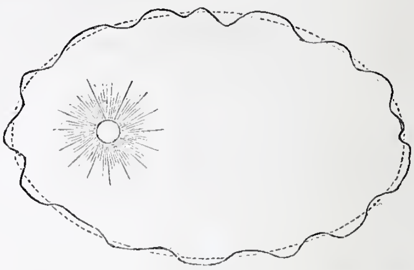
Our remarks in last chapter on the mutual attraction which is not only exerted by the sun upon all the planets, and by the planets upon the sun, but which is exerted by the planets upon each other, producing what are called *perturbations* by astronomers, will now make it evident, that although we may accept Kepler's *first* great law, assigning them elliptic orbits, as in the main correct, still we must do so with some degree of limitation. Were our system composed of the sun and a single planet, or were the sun the only body in the system which possesses the power of attraction, the single planet on the former supposition, and all the planets on the latter, would pursue their elliptic orbits with the most undeviating accuracy; so that, if one of them could trace out a visible path in one revolution in its orbit round the sun, it would traverse exactly the *same path* in every future revolution for ever. But we must look upon every individual planet and satellite in the solar system, as not only under the influence of the powerful attraction of our mighty central orb, but also under that of all the other individual planets, which, in their turn, are to a greater or less degree under its influence. Instead, therefore, of a planet following a regular elliptic path, as was supposed by Kepler, it will, in obedience to the great law of universal gravitation, follow an elliptic path more or less irregular. In the following figure, the dotted line points out the regular elliptic orbit which a planet would pursue, if only under the influence of the sun's attraction; while the black crooked line shows the path which it is compelled to follow, by the disturbing influence of the attractions of the other planets. (See fig. 18.)

Since the course and motions of a planet, then, are ever varying by these disturbing influences of the other planets in the system—at one time pulled to this side, at another time to that side, from its continuous onward path; and at one time retarded in its motion, and at another time accelerated—how can we calculate the amount of these perturbations, so as to fix its period of revolution, and write its history for coming ages?

Newton demonstrated that the power by which any orb attracts any other orb is *directly* in proportion to the *mass* or *weight* of the attracting body, and that this power will *diminish* according to the *increase* of the square of the distance between them. To enable us, therefore, to calculate the amount of attractive influence which one orb will exert upon another, not only must we know the distance between them, but we must also know their *weights*, or the quantities of matter in each.

To an individual who hears this for the first time, it will appear very surprising, if not almost incredible, that the astronomer can weigh the planets; that he can not only tell their relative weights, but he can tell the absolute number of pounds avoirdupois in the sun, and in every individual planet and satellite in the system, with a great degree of accuracy.

Fig. 18.



To estimate, however, both the relative and absolute weights of the sun and all the planets, is not nearly so difficult a task as might, at first sight, be supposed. We have only to remember that the distance which the earth causes a body to fall in a given time, near its surface, is a measure of its attractive power; and, as the attractive power is in direct proportion to the weight of the attracting body, the distance fallen is, in one sense, a measure also of the earth's weight. But the distance to which the earth causes the moon to be deflected from a tangent to its orbit, in a given time, is also a measure of the strength of its attraction, and is consequently a measure of its weight. It is evident, therefore, that the distances to which the individual planets are deflected from tangents to their orbits, in a given time, by the power of the sun's attraction at their different distances from his centre—all afford separate data for calculating the weight of the sun.

It is known, for example, that the strength of the sun's attraction causes the earth to be deflected from a tangent to its orbit, rather more than twice the distance, in the same time, which the earth causes the moon to be deflected; and, if the sun's attraction exerted this force upon the earth at the same distance which is between the earth and the moon, it would follow, that the weight or mass of the sun must be rather more than double that of the earth; but the sun is 400 times farther from the earth, than the earth is from the moon; and as attraction diminishes, not as the distance increases, but in proportion to the square of the distance, the mass, or weight of the sun, to exert such a power at such a distance, must be equal to as many earths as the square of 400, multiplied by rather more than 2; or, to state the exact amount, equal to 389,551 times the weight of the earth. Knowing, therefore, the relative weight of the earth by the force of its attraction upon the moon, we can thus calculate the weight or mass of the sun, compared to that of our earth, by the force of his attraction upon any individual planet.

In the same manner, it is easy to calculate the weight of all the planets which are attended by moons. We have only to know the period of the revolution, and the distance of the satellite from its primary planet, to be able to determine the distance to which it is deflected from a tangent to its orbit, in a given time, and thus to arrive at the weight of the planet, compared to the weight of our earth.

But in the case of a planet without a moon, such as Mercury, Venus, Mars, &c., the question is much more diffi-

cult. We can only arrive at their weights by the intricate process of calculating the amount of their disturbing force, individually and collectively, upon any neighbouring planet of known weight. When any two planets, for instance, whose weights we wish to ascertain, are in such positions in their orbit as to retard, by their united attraction, the motion of a third planet of known weight, we note the amount of this retardation; when they are in such positions as to accelerate the motion of the third, we also note the amount of the acceleration; when, again, they are in such positions as that the one retards, while the other accelerates the motion of the third, we note the difference; and knowing the sum of two numbers and their difference, we can calculate the amount, and thus arrive at the weights of the two planets.

In these different ways, the weights of the large planets, compared to the weight of the sun, have been ascertained to be as follows; the masses of the asteroids, Vesta, Juno, Ceres, Pallas, &c., being too minute to admit of measurement:—

Weight of Sun equal to............	4,865,751	times that of	Mercury.
" "	401,839	"	Venus.
" "	389,551	"	Earth.
" "	2,680,337	"	Mars.
" "	1,048	"	Jupiter.
" "	3,501½	"	Saturn.
" "	24,905	"	Uranus.
" "	18,780	"	Neptune.

Having ascertained the weight of the different planets compared to that of the sun, and the weight of the sun compared to that of the earth, we have only now to determine the absolute weight of the earth, to be able to calculate the absolute weight of the sun, and all the planets, and to tell the number of pounds avoirdupois in each.

How then can we arrive at the absolute weight of the earth? By comparing the force of the earth's attraction with the attractive force of any body, or mass of matter, the weight of which is either exactly known, or can be calculated with a tolerable degree of accuracy. This has been accomplished by accurately observing the amount of attraction exerted by large leaden balls, whose weights were known, upon small ones in an air-tight room; and again, by noting the amount to which a pendulum was deflected from the perpendicular, or plumb line, by the attractive power of a large mountain mass, whose weight could be pretty correctly estimated. By these experiments, it was found that the weight of the earth was about five times the weight of a globe of water of equal size. "The number of cubic miles in the earth," says Professor Airy, "is about 259,800,000,000; each cubic mile contains 147,200,000,000 cubic feet; and each cubic foot, upon the average, weighs 5·67 times as much as a cubic foot of water, or 354 lbs. 6 oz. avoirdupois."

Having thus shown the mode of ascertaining the weights of the primary planets, we have only now to calculate the weights of the different moons or satellites. This is done in nearly the same manner as that adopted for weighing the planets without moons; viz., by observing the amount of their individual disturbing influences upon their companion satellites, and upon their primary planets. In the case of our moon this is not very difficult, by calculating the amount of her disturbing influence upon the motions of the earth, and upon the waters on its surface; in the case of the moons of Jupiter, Saturn, &c., we have not only the amount of their individual and separate influence upon the motions of their primaries to aid us, but the amount of their mutual attractions upon each other to assist in the calculation.

When Sir Isaac Newton pushed his theory of universal gravitation to its remote consequences—when he saw not only the sun, but every individual planet, and every individual satellite, endowed with the magnetic power of attracting, and, to a greater or less degree, disturbing the motions of every other planet and satellite in the system—when he saw planet swaying planet, and satellite bending the orbit of satellite; he feared that he had thus reduced complexity out of simplicity, and brought order and harmony into disorder and destructive confusion. He hoped that the advance of science might render his theory of universal gravitation compatible with the stability of our system, but he went down to the grave with the conviction, that the disturbances, or perturbations, caused by the mutual attractions of the various bodies in the solar system on each other, would go on accumulating till their original orbits would lose every trace of their simplicity, and, unless readjusted by the hands of the Creator, would end in the utter destruction of the system.

In the days of Newton, mathematical science had not reached such a degree of exactness and high perfection, as to enable him to solve the difficulty—to prove that in the very disturbances of the motions and orbits of the planets, lay the grand secret of the stability of the system, and to demonstrate to the weak and puny intellect of man, how wondrous are the ways of the Almighty, and how perfect the work of his hands!

The astronomer viewed the planets revolving around the sun—in the same direction—at different *distances* from his surface; in *orbits* more or less elliptical, or oval; in *planes* more or less inclined to the *plane* of the sun, which we shall call the *plane of the equator*,* the planes of all the planets being variously inclined to one another; the perihelion and aphelion points of these orbits, not all in one straight line with the sun, nor all in one side of that orb, but in every different point around him; and the various satellites exhibiting the same peculiarities in their motions and orbits around their primaries. And because no finite being could construct a system upon such principles, even with the assistance of the laws of gravitation and motion which were then known, capable of enduring for ever, the astronomer vainly imagined that our system of a central sun, with his surrounding planetary orbs, contained within itself the seeds of its own destruction. He even saw the orbit of our moon drawing closer and closer to the earth from century to century; the orbits of some of the planets were gradually becoming more and more circular, those of others more and more elliptical; the inclinations of the planes of their orbits were changing with regard to one another, and with regard to the plane of the sun; the perihelion and aphelion points of the orbit of every planet, instead of being fixed in space, slowly revolved around the sun in vast periods; nothing, in short, was uniform and invariable, except the directions in which the planets moved, and the motions of the perihelion and aphelion points of their orbits. If any or all of these changes, therefore, which were caused by the mutual attractions of the various planetary bodies, went on increasing—if their orbits continued to expand or diminish, or if their planes became more and more inclined—sooner or later the great catastrophe must come, and the whole system reduced to its primitive chaos.

Thanks, however, to the indefatigable labours of the continental astronomers—to the master-minds of Clairaut, of D'Alembert, of Euler, of Lagrange, and of the celebrated Laplace—"a name which in this country we have been taught to calumniate, but which every friend of science will associate with her noblest efforts, when the days of prejudice and illiberal sentiment are past."† These profound mathematicians and astronomers subjected every agitated question, as to the stability of the system, to the most rigorous and searching analysis; and, by steps so abstruse and intricate, as to require a perfect knowledge of the higher branches of mathematical science to follow them, settled every question in the most absolute manner; having reached the conclusion that the most admirable and effectual means were adopted in every instance to secure the permanency of the entire system in all its integrity for ever. How different from a system thrown together by chance, or resolving itself into order from the operation of secondary causes! Every planet and every satellite has been weighed and poised; every orbit exactly adapted for the planet which moves around it; the inclination of the plane of every orbit placed at the proper angle; so that, if it were possible to transpose any two planets into each other's places, this change would be destructive to

* The plane of the orbit of a planet may be compared to the end of a drum, the wooden rim representing the *orbit*, and the tightly fitting leather included, representing the *plane*.

† Sir D. Brewster's Edinburgh Encyclopædia, Art. 'Astronomy.'

the stability of the whole system; even the interchange of the orbit of our moon with that of another, would inevitably be attended with fatal results. It is true, as an eloquent writer remarks, that "mutation and change are everywhere found; all is in motion; orbits expanding or contracting, their planes rocking up and down, their perihelia and nodes sweeping in opposite directions round the sun; but the limits of all these changes are fixed; these limits can never be passed; and at the end of a vast period, amounting to many millions of years, the entire range of fluctuation will have been accomplished; the entire system, planets, orbits, inclinations, eccentricities, perihelia, and nodes, will have regained their original values and places, and the great bell of eternity will have then sounded ONE!"

To enter with any degree of minuteness into the complex and difficult subject of *perturbations*, would be quite incompatible with the object of the present treatise, which is intended to afford merely to the *uninitiated*, a glance at a few of the first principles of astronomical science. We shall, however, give a few examples in illustration of the effects of the mutual attractions of the heavenly bodies upon one another in deranging and altering their primary arrangements.

If the moon were solely under the influence of the earth's attraction, or if the earth and moon were invariably at the same distance from the sun, the moon's orbit would always be of the same size, and her mean motion would be of the same degree of quickness, from year to year, for ever. But as the earth moves in an elliptic orbit round the sun—that orb occupying, not the centre, but one of the foci of the ellipse—it is plain that the earth and moon, in sweeping round this orbit, are considerably farther away from the sun at one period of the year than at another. And since, by the law of attraction, the sun has a greater influence upon the motions and orbit of the moon, the nearer she approaches his surface, it follows that, when the earth is at its perihelion, or nearest the sun, the attractive influence ef that orb tends to draw the moon away from the earth, to widen her orbit, and to retard her motion; when, again, the earth is at its aphelion, or farthest distance from the sun, his attractive power over the moon is considerably diminished, she is more under the attraction of the earth, her orbit is therefore narrowed, and her motion accelerated. It is evident then, that, by the disturbance of the sun's attractive force, the moon's orbit, and her periodic times, or the periods she takes to revolve around the earth, are very irregular in different parts of the earth's orbit; and to enable us to arrive at a close approximation to the moon's mean period of revolution, it is necessary to note her exact periods for a number of revolutions, 1000 for instance, and then take an average. This has been done with great exactness, at several distant periods of the world's history. It was performed by the Babylonians, by the Arabian astronomers, and with the utmost precision towards the end of last century. But by instituting a comparison between the eclipses recorded by these different observers, it was discovered that three thousand years ago the moon required a longer period to perform a mean revolution round her orbit than she now requires. What can be the cause of this extraordinary phenomenon? Are we to throw discredit on the eclipses and early observations recorded by the primitive observers, or are we to allow their correctness, and set down this wonderful anomaly to the gradual diminution of the sun's attractive power over the orbit and motions of the moon? The observations of the early astronomers were recorded with such scrupulous minuteness and accuracy, that it was impossible to deny their correctness; and philosophers were obliged to admit that the moon's mean motion was very slowly, but certainly, becoming swifter and swifter, and her orbit narrower and narrower; in short that she was drawing closer and closer to the earth, and if such an approximation were allowed to proceed, that, after the lapse of an immense period, she would be precipitated on the earth, involving, not only our planet, but the whole system in irretrievable ruin.

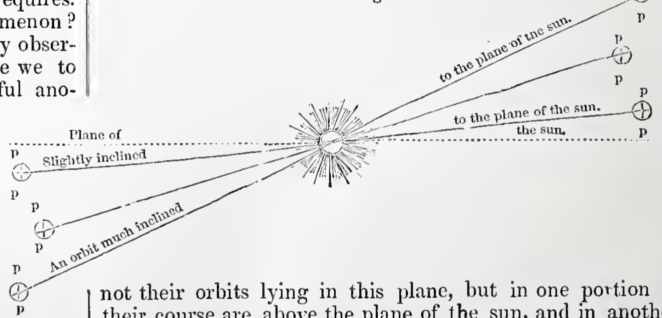
Long had astronomers bewildered themselves with all sorts of conjectures as to the cause of this mysterious and portentous phenomenon, but none of them were able to solve the problem, till Laplace brought his mighty intellect and profound knowledge to bear upon the solution of the mystery. After an amount of labour in the higher departments of mathematical analysis, which has been the wonder and admiration of succeeding astronomers; after weighing and poising all the planets, and all their secondaries, with the utmost accuracy; and after calculating the effect of their mutual attractive powers upon the motions and orbits of each other, and of their combined influence upon the earth, with the most extraordinary precision, Laplace discovered that, by the joint action of all the planets, the figure of the earth's orbit was slowly changing, that for millions of years it had gradually been becoming more and more circular, that at the end of an immense period it would be a complete circle, and then it would commence gradually to resume its elliptic form. At the end of many millions of years, the earth's orbit will have reached its greatest degree of ellipticity, when it will again recommence to assume the circular form, and it will thus continue to vibrate backwards and forwards, to expand and contract, in periods so vast as to stun the imagination, "like some mighty pendulum beating the slowly ebbing seconds of eternity!"

So slow, indeed, is this motion, that, in the space of three thousand years, its effect upon the moon has only been sufficient to bring her four of her own diameters in advance of the position she would have occupied had her orbit and mean motion remained invariably fixed. Had it not been for this acceleration of the moon's mean motion, produced by the slowly diminished influence of the sun's attraction from his increased distance, the change in the figure of the earth's orbit might never have been discovered; but it is impossible for the orbit of the earth to change in the slightest degree without at once producing an indirect and greatly exaggerated effect upon the moon's mean motion, not perhaps perceptible in a number of revolutions, but sooner or later becoming quite palpable to the scrutinizing gaze of the astronomer.

It was also discovered that the orbits of all the other planets were undergoing a slow but constant alteration of form; some becoming more and more circular; others becoming more and more elliptical, or oval; but the profound researches of Lagrange have completely, and in the most satisfactory manner, settled the question as to their effect on the stability and physical welfare of our system; and demonstrated that these changes in the eccentricities of the planetary orbits were comprised within very narrow limits, and that the very causes by which they were produced would ultimately restore them to their primitive arrangement.

Conceive a level plane, like the surface of still water, extended in every direction to a boundless distance; call this the *plane of the sun*, and suppose that mighty orb placed in its centre. The various planets, in revolving round him, have

Fig. 19.



not their orbits lying in this plane, but in one portion of their course are above the plane of the sun, and in another portion below it; nor have they their orbits all in the same plane, or inclined equally to that of the sun, but they revolve in planes slightly inclined to one another. (See fig. 19.)

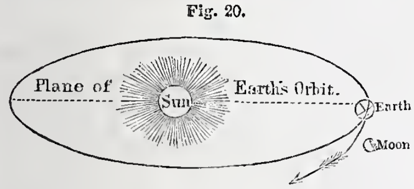
The above figure gives a rude and exaggerated represen-

tation of the plane of the planets' orbits, with their various inclinations to the plane of the sun, which is also called the plane of the equator.

It will be obviously apparent, from a careful inspection of the above figure, that the less inclined the plane of the orbit of any planet to that of the sun—or the nearer it coincides with that plane—the less will be the variation of its seasons; if a planet revolved in the plane of the sun, there would be no alternation of seasons, but a perpetual spring from month to month, and from year to year, for ever. The more the orbit of a planet is inclined to the plane of the sun, the greater, on the other hand, is the variation of the seasons; and if the plane of the planet's orbit should ever diverge as far from the plane of the sun, as that the one would be perpendicular to the other, the extremes of winter and summer would be intolerable.

Now it has been known, from a very remote period, that the plane of the earth's orbit, called also the plane of the ecliptic, has been shifting its position, and becoming less and less inclined to the plane of the sun. The amount of this shifting has been progressing for an immense period at the rate of about 48 seconds, or $\frac{1}{75}$th part of a degree, in a century. The same thing was discovered to be going on to a greater or less amount with the inclinations of the orbits of all the other planets; they were either diverging farther from, or converging nearer to, the plane of the equator. These changes were all produced by the mutual attractive influences of the planets upon each other, or by the attractive influences of their moons, as shown in the following figure, where the moon is represented as drawing the earth out of the orginal plane of its orbit. (See fig. 20.)

Fig. 20.



If such a state of things were to continue, the effects might be quite insensible in short intervals of time; but in the course of ages, the accumulated effects would inevitably disturb the existing order of things, and ultimately destroy the system.

Here, again, the giant labours of Lagrange come to our aid, and inspire us with unwavering confidence in the stability of the universe, and with the most profound admiration at the transcendant skill of the Great Architect! By an analytical process, of which it is impossible here to convey the faintest conception, he proved that the variations of the inclinations of the planetary orbits were comprised within very narrow limits; that the causes which produced these variations would ultimately restore the inclination of the plane of the orbit to its primitive condition, to recommence its variation anew; thus oscillating up and down, in periods of which we can form no idea, but never diverging so far from its original position, as materially to disturb the harmony of the system. The plane of the earth's orbit vibrates up and down, its mean position ranging within the limits of about 1 degree, 21 minutes.

In remarking that the planes of the planets' orbits are variously inclined to the plane of the sun, we mentioned that one portion of their planes was above, and another portion below, this imaginary level surface; the points, then, where the planes of the planets come in contact with, and pass through the plane of the sun, are called the planet's *nodes*; and as we have already stated, the point in the elliptic orbit of a planet which is nearest the sun, is called its *perihelion*. It was discovered that these points in a planetary orbit were never at rest, but regularly revolved round the sun in one direction; the perihelion points, and, consequently, the aphelion points, revolved round the sun in the direction of the planet's motion, but at so slow a rate that the perihelion of the earth's orbit requires *one hundred and eleven thousand years* to sweep round the sun! The perihelion point of Jupiter's orbit advances so slowly in the same direction, that it requires 186,207 years, while that of Mercury's orbit requires 200,000 years to complete its circuit.

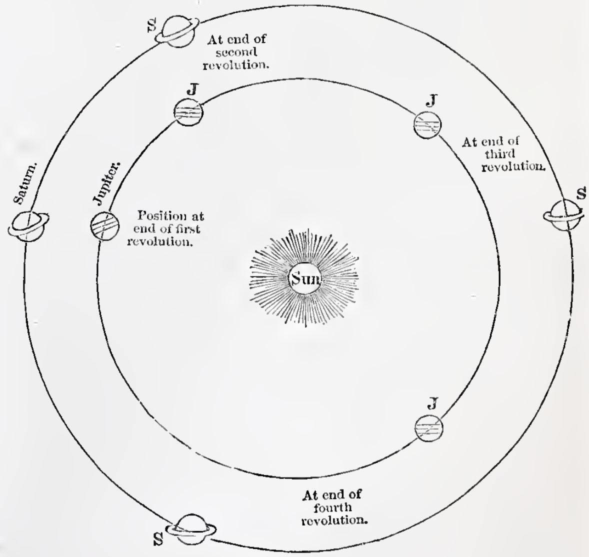
As the perihelion points of the orbits advance in the direction of the planets round the sun, it follows that the *nodes* must have a retrograde motion, which will circulate round the sun in a contrary direction in the same time.

A very remarkable circumstance in the mechanism of the system requires special mention, as illustrative of the most extraordinary design on the part of the Creator; viz., that the periodic times of no two neighbouring planets in the system are in exact ratio to one another. If our planet performed two exact revolutions for another's three; or three for another's four; or two for another's five; at the end of each of these periods, the same perturbations would have recurred over and over again, ready to be repeated under the same circumstances as before: in such a case, the perturbations would go on accumulating, and eventually undermine the stability of the system.

A very near approach to such a state of things exists in the case of Jupiter and Saturn. Five of Jupiter's periods are *nearly* equal to two of Saturn's; and the consequence is, that the mean period of revolution of the one was found to be on the increase, and the other on the decrease. Had five of Jupiter's periods been *exactly* equal to two of Saturn's, these derangements would have progressed in the same direction, and led to the destruction of the system, as it was supposed they were certainly doing, till Laplace discovered the true state of the case. In the circumstance that five of Jupiter's periods were *not exactly* equal to two of Saturn's, lay the safety and permanence of the system. At the end of every one of these periods, one of these planets had got a little in advance of the other; little and little accumulates in the course of ages to a considerable quantity, and by-and-by the points of conjunction of the two planets in their orbits will be very different, the original arrangement will be restored, and order and harmony preserved for ever. (See fig. 21.)

What an ample compensation for the labour of studying astronomy, to be enabled to contemplate a system so grand!

Fig. 21.



What a wonderful balancing of forces! What delicate mechanism! Is the system subject to perturbations and deranging influences? Whenever these perturbations would lead to results incompatible with the stability of the system, they are invariably of a compensatory nature, after a time effecting a complete readjustment of the derangement, and thus correcting their own effects. Whenever, on the other

hand, the perturbations produce mutations which do not involve stability, such as the revolution of the perihelion and nodes, these mutations are allowed to go on for purposes which the mind of man has not yet dared to fathom. The idea of an individual who cannot see design, written in characters of gold throughout the whole of this mighty system, but attributes its organization to chance, excites a feeling in the mind which it is difficult to express, and which is very analogous to that which must have filled the soul of the inspired writer when he said, that "The *fool* hath said in his heart, 'There is no God.'"

INORGANIC CHEMISTRY.

CHAPTER VIII.

COMBINATIONS OF THE NON-METALLIC BODIES.

NITROGEN AND OXYGEN.

These two elements, when mingled in the gaseous state, show no tendency to unite. By indirect methods, however, they may be combined, and form five compounds, of which the most important is nitric acid, consisting of 1 eq. nitrogen with 5 of oxygen = NO^5. But here the question may arise, "What is an acid?" At the commencement of the century, this name was applied to such oxidized bodies as have a sour taste, redden litmus-paper, and neutralize alkalies or bases. By degrees this definition has been modified. Numerous acids have been discovered containing no oxygen, such as the fluoboric, hydrochloric, hydrosulphuric. It has been found that carbonic acid is incapable of fully neutralizing the more powerful alkalies. The sour taste and the action upon vegetable colours are, of course, wanting, whenever an acid, like the silicic, is insoluble in water. The term "acid" is, therefore, now extended to every compound body which unites with bases, such as potash or soda, forming with them compounds analogous to those produced by the sulphuric, nitric, or some other normal acid. Except in a few instances, it depends upon circumstances whether a given body acts as an acid, or plays the correlative part of a base. Thus, arsenious acid, alumina, peroxides of tin, gold, platinum, &c., in contact with energetic bases, act as acids; but, if treated with powerful acids, they assume the function of bases. This consideration is the more important, as we are always inclined to forget that nature rarely conforms to those sharp and broad lines of demarcation which we draw for our own convenience. Nitric acid may be formed in a direct manner, by mixing nitrogen and oxygen gases in a receiver, at the bottom of which is placed a little water, and passing a succession of electric sparks through the mixture. The water gradually acquires an acid taste and reaction. In this manner, nitric acid is actually generated in the atmosphere during electric storms, and, combining with ammonia, imparts to thunder-rain its peculiarly fertilizing properties. It is also formed during the electrolysis of water, the oxygen of which unites with the nitrogen of the atmosphere; and during the decay of certain organic compounds. In various parts of the earth this acid is found in conjunction with potash, as saltpetre (nitre, nitrate of potash), or with soda, especially in the desert of Atacama, in Upper Peru. To prepare the acid, 100 parts of saltpetre, purified by repeated crystallization, are distilled in a glass retort, along with 96 parts of oil of vitriol. The process is continued until the residue in the retort becomes tranquil, and no more drops pass over. If nitrate of soda is used, only 58 parts of sulphuric acid are required. The materials should not fill more than half of the retort, to prevent boiling over. On a large scale, the operation is conducted in horizontal cast-iron cylinders; but the product thus obtained (aquafortis, or commercial nitric acid) is always contaminated with chlorine, sulphuric and nitrous acids. The liquid acid, in its most concentrated state, has a specific gravity of 1·564, and consists of one atom of real acid united with one atom of water. It has a faintly pungent odour, an intensely sour taste, corrodes most organic substances, colours the skin yellow, oxidizes and dissolves most metals, and absorbs water from the atmosphere. This acid is very extensively used in many arts and manufactures, as well as in the laboratory. Till lately, it was supposed that the atom of water was essential to its existence. But Deville, by treating nitrate of silver with dry chlorine, has obtained anhydrous nitric acid in the form of transparent, colourless, six-sided crystals. If a quantity of nitric acid is exposed to sunlight, its colour gradually deepens to a yellow, and even to an orange shade. This is owing to the presence of nitrous acid, NO^4, formed by the decomposition of a portion of the nitric acid which has lost one eq. of oxygen. Nitrous (or hyponitric) acid is prepared by distilling dry nitrate of lead at a high temperature. Its colour varies with the temperature; below 32° F. it is colourless, from 32°—50° pale yellow, and at higher temperatures orange. Its vapour, when mixed with other gases, is not condensed by exposure to cold. It is of very little practical importance; but its presence greatly modifies the properties of nitric acid, the powers of which, as an oxidizing agent, are much feebler when pure than when contaminated with nitrous acid.

Hyponitrous acid, NO^3, (called also, by some chemists, nitrous acid,) is prepared by heating 1 part of starch in 8 parts nitric acid of sp. gr. 1·25, and passing the products through a tube filled with chloride of calcium into a receiver surrounded with a freezing mixture. It is a deep indigo-blue liquid, which boils below 32° F., and gives off orange-red fumes. It does not combine in a direct manner with the alkalies; but its salts (commonly called *nitrites*) may be prepared by cautiously heating the corresponding nitrates. Much confusion prevails concerning the acid compounds of nitrogen, owing, in part, to the fact that they have received different names from different authors.

Binoxide of nitrogen (nitric oxide), NO^2.—If some fragments of copper wire be put in a retort, and nitric acid added, an orange-red gas, of a suffocating odour, is immediately disengaged. If passed through water, and collected in a receiver in the usual manner, it becomes colourless. If now some bubbles of oxygen or of common air be passed up into the receiver, the red tinge instantly reappears. The water then gradually rises, and absorbs a part of the gas, the remainder becoming again colourless. This alternate change of colour may be exhibited several times, if the quantity of gas be sufficient. The explanation of these phenomena is very simple. When nitric acid acts upon a metal, it is decomposed; three equiv. of its oxygen combine with the metal, whilst the remainder, NO^2, escapes as a *colourless* gas. But this gas, on meeting with oxygen, combines with it, forming an orange-coloured vapour highly soluble in water. The gas in the retort appears orange, because common air was present at the commencement of the operation—that in the receiver colourless, as the orange fumes had been absorbed by the water in passing.

Lastly, if nitric acid, combined with ammonia, be briskly heated in a glass retort, a colourless gas is given off, called *nitrous oxide*, or, more popularly, *laughing gas* = NO. Unlike the other oxides of nitrogen, it may be respired for some time without danger, producing upon the human body the most remarkable and varied effects, resembling those of alcohol, or rather of opium, or hachiche. It is incombustible, but burning bodies immersed in it glow with greater brilliance than in common air.

NITROGEN AND HYDROGEN.

These elements combine to form a most remarkable gas, ammonia, NH^3, which may be considered as a characteristic instance of basic substances. Bases, or alkalies, as they are less correctly styled, possess properties in many respects opposite to those of the acids. If soluble, they have in general a soapy, burning taste, and restore the original colour of vegetable blues which have been reddened by acids. They also change the yellow of turmeric paper to a reddish brown. The only property, however, common to all bases, is that of combining with acids, so as to form compounds analogous to those produced by potash, soda, or ammonia. Ammonia is a light,

colourless gas, of a pungent and exciting odour. It is slightly combustible, and does not support the combustion of other bodies. By great pressure, and the application of cold, it may be condensed into a liquid, and even into a solid. In the gaseous state, it is prepared by mixing 1 part of powdered sal-ammoniac with 2 parts of powdered lime, and gradually heating the mixture in a glass retort. Water greedily absorbs ammoniacal gas to the extent of 670 times its own volume. It has then a specific gravity of 0·875, and possesses the odour and basic properties of the gas. Ammonia, like many other gases, is absorbed, to a very considerable extent, by recently ignited charcoal, by an action similar to that of spongy platinum. This explains the efficacy of charcoal as a disinfectant, and its employment in purifying water. Powdered gypsum, likewise, absorbs ammonia, whence its value as a manure. This property becomes still more manifest, if it is moistened with dilute sulphuric acid. Trays of this mixture have been placed with good effect in stables and cowhouses, in order to prevent the health of the animals from being affected by ammoniacal fumes. Ammonia is present, to a small extent, in the atmosphere, where it contributes to the nutrition of plants. It is also generated when zinc and iron are dissolved in nitric acid, and during the decay of nitrogenous substances. Its main source is, however, in the refuse of gas-works—a matter which, worthless and offensive as it may appear to the unthinking, is to the chemist an almost inexhaustible mine of valuable and interesting products.

Nitrogen combines also with two equivalents of hydrogen, forming *amide*, or *amidogen*, and with four, forming *ammonium*. These substances have not yet, indeed, been isolated, but their existence is inferred from various phenomena. The former, in its chemical relations, is analogous to chlorine, iodine, &c. The latter acts as a metal, forming an amalgam with mercury.

CARBON AND OXYGEN.

On observing a fire of coke or charcoal, a pale blue flame is perceived hovering over the ignited mass. This is produced by the combustion of *carbonic oxide*, the lowest stage of oxidation of carbon, CO. This gas is most conveniently prepared by heating finely-powdered ferrocyanide of potassium with 8 or 10 times its weight of oil of vitriol. It is inflammable, does not support combustion; it is tasteless, and nearly inodorous. Animals immersed in it die instantly; and even when mixed with a large amount of common air, it is extremely deleterious. In burning, it takes up another equivalent of oxygen, and becomes carbonic acid.

If dilute sulphuric or hydrochloric acid be poured upon chalk, limestone, marble, or oyster-shells, brisk effervescence ensues, and bubbles of gas are given off. If the operation is performed in a retort, so that the product may be collected, it is found to be *carbonic acid*, CO^2. This is a gas distinguished by its great specific gravity (1·5); hence it can be poured from one vessel into another, like water, though, if left standing uncovered, it gradually escapes and mingles with the air. It has a pungent odour and faintly acid taste, and communicates these properties to liquids saturated with it, such as soda-water, ginger-beer, and the water of certain mineral springs. It reddens litmus, but the stain soon disappears on exposure to the atmosphere. It is rapidly absorbed by caustic alkalies. If a little solution of potash be poured into a tube or phial filled with the gas, and the aperture be then closed with the thumb, and the phial briskly shaken, the gas is absorbed with such rapidity as to cause a partial vacuum, so that the phial clings to the thumb like the exhausted receiver of an air-pump. If a current of the gas is passed into lime or baryta water, the liquid soon becomes turbid, and a white sediment of carbonate of lime or baryta is deposited. Water impregnated with carbonic acid is, however, capable of holding a certain amount of carbonate of lime in solution. On boiling the water, the free carbonic acid is expelled, and the carbonate of lime is precipitated, forming a deposit on the bottom and sides of the vessel, as may often be seen in tea-kettles, and especially in steam-boilers. Carbonic acid in a pure state is irrespirable, and proves almost instantly fatal to animals plunged into it. Even when largely diluted with common air, it still produces giddiness and fainting. It is not only incombustible and incapable of supporting combustion, but seems to exert a positive influence in extinguishing flame. Hence a burning candle is frequently lowered into cellars, wells, and other places, where the gas is suspected to have accumulated, in order to ascertain whether they may be entered with safety. If present in such localities, it may be removed by means of slaked lime. This gas occurs in the atmosphere to a small but variable extent; it is also given off in the combustion of all carbonaceous bodies, in fermentation, and in the respiration of animals. This may be proved by breathing through a tube into some lime-water, when a white precipitate will soon appear. It is one of the feeblest of all acids, being expelled from its combinations by nearly all others.

With due precautions, carbonic acid may be rendered liquid, and even solid. The experiment is performed in a cast-iron cylinder of enormous strength, and requires great caution. In one instance, the massive iron cylinder was torn in pieces, and the fragments flying about, cut off the legs of an assistant, fortunately the only person present, and killed him on the spot. The liquid is colourless, transparent, lighter than water, and exerts, at 12° C., a pressure of 58 atmospheres. If allowed to escape from a jet, it evaporates with such rapidity, that a portion solidifies from the intense cold produced. Solid carbonic acid is a white flocculent mass, resembling snow. A thermometer plunged into it, sinks to 135° F. If pressed upon the skin, it raises a blister. From its enormous expansive force, liquid carbonic acid would be highly valuable as a motive power, could a method be discovered of managing it with safety.

CARBON AND HYDROGEN.

The compounds formed by these two elements are almost innumerable; but, with the exception of two, they belong to the province of organic chemistry. *Marsh gas* (light carburetted hydrogen, fire-damp) $= CH^2$. This gas is formed during the slow decay of vegetable matter. If the mud at the bottom of weedy ponds and ditches be agitated with a stick, the gas rises to the surface in bubbles, and may be collected. It is found also in coal-mines, generated during the decomposition which transforms wood into coal. It is colourless, tasteless, highly inflammable, and, when mixed with oxygen or atmospheric air, exploding with great violence. *Olefiant gas*, C^2H^2, is one of the principal ingredients of common coal gas. It is obtained in a state of purity by heating alcohol in a retort with an excess of oil of vitriol. It is very combustible, and gives an exceedingly luminous flame.

SULPHUR AND OXYGEN.

Sulphur and oxygen combine in seven different proportions, forming a series of acids, of which two only will require particular mention.

Sulphurous acid, SO^2.—When sulphur is burned in the air, or in oxygen, it yields pungent vapours of sulphurous acid. For experimental purposes, it is best obtained by heating sulphuric acid along with copper, mercury, or powdered charcoal. It is liquefied at a pressure of 3—5 atmospheres, and solidified by means of intense cold. The gas is absorbed by water to a considerable extent; but the solution, if exposed to the air, is gradually converted into dilute sulphuric acid.

Sulphuric acid, SO^3, is one of the most important compounds with which chemistry has made us acquainted. It is met with in two states—the fuming, or Nordhausen acid, and English acid, or oil of vitriol—both of which contain a certain quantity of water. The former, prepared by distilling sulphate of oxide of iron at a red heat, is a brown oily liquid, of specific gravity 1·896. It consists of two equivalents of real acid united to one of water. Common oil of vitriol is prepared by burning sulphur mixed with $\frac{1}{8}$th part of saltpetre, in a large chamber lined with leaden plates, the floor being covered with water. The acid liquid thus obtained is concentrated, first in leaden pans, and afterwards in retorts of glass or platinum. It is a colourless, transparent, oily liquid, inodorous and corrosive. It becomes very hot when rapidly mixed with water. If exposed to the air, it gradually attracts watery vapours, and be-

comes weaker. Its specific gravity is 1·848. The water combined with this acid must not be confounded with such water as may be subsequently added. The latter may be removed by evaporation, but if the attempt be made to separate the former by a higher temperature, the whole distils over together. Anhydrous sulphuric acid is obtained by distilling the fuming acid at a gentle heat. It forms white, opaque feathery masses, which give off dense white fumes on exposure to the air. It does not redden litmus-paper, and its combination with ammonia is a body totally distinct from the sulphate of ammonia formed by the hydrated acid.

The applications of sulphuric acid in the arts defy enumeration.

The remaining acids of sulphur are—hyposulphurous, $S\,O$; pentathionic, $S^5\,O^5$; tetrathionic, $S^4\,O^5$; trithionic, $S^3\,O$; and hyposulphuric, $S^2\,O^5$.

SULPHUR AND HYDROGEN.

When sulphuret of iron is covered with dilute sulphuric acid, a colourless gas, of most offensive odour and poisonous properties, is given off. This is sulphuretted hydrogen, or hydrosulphuric acid, $H\,S$. This gas is naturally generated when animal or vegetable substances containing sulphur are allowed to decompose, such as eggs, cabbage leaves, &c. It is a constant and most dangerous ingredient in the exhalations from graveyards, unclean slaughter-houses, cesspools, and sewers. It attacks most metals, turning them a brownish-black, especially lead and silver. Notwithstanding its unpleasant and dangerous properties, it is of the highest value in chemical investigations.

SULPHUR AND CARBON.

The *bisulphide of carbon*, $C\,S^2$, is a dense, volatile, transparent liquid, of nauseous odour, prepared by passing the vapour of sulphur over red-hot charcoal. It is of some use in dissolving resins.

PHOSPHORUS AND OXYGEN.

Phosphoric acid, $P\,O^5$, is prepared either by oxydizing phosphorus with nitric acid, or, on the large scale, by burning bones to whiteness, treating them with dilute sulphuric acid, decanting the clear liquid from the sediment and concentrating. It occurs in three distinct states—metaphosphoric acid, pyrophosphoric acid, and ordinary phosphoric acid—which, when forming salts, take up 1, 2, and 3, equiv. of base respectively, and differ otherwise in their reactions. Phosphoric acid is a solid, transparent, deliquescent mass, inodorous, of a very pleasant taste, and perfectly innocuous. On the contrary, *phosphorous acid*, $P\,O^3$, formed during the slow combustion of phosphorus, is exceedingly poisonous.

PHOSPHORUS AND HYDROGEN.

Phosphuretted hydrogen, $P\,H^3$, occurs in two distinct conditions. In the one form it inflames spontaneously on coming in contact with oxygen, and burns with a brilliant light. It has a most offensive odour, resembling that of putrid fish, and is even more poisonous than sulphuretted hydrogen. It is prepared by boiling fragments of phosphorus in solution of caustic potash. The other variety, formed by treating phosphide of calcium with hydrochloric acid, does not ignite spontaneously, but is nevertheless very combustible. Phosphuretted hydrogen is a base, and forms compounds analogous to those of ammonia.

Phosphorus and sulphur form a number of explosive compounds.

OZONE.

This name is applied to a remarkable substance, not as yet thoroughly understood. It was, at one time, supposed to be an element, but is now generally regarded either as a modification of oxygen, or as a peroxide of hydrogen. It is formed either by the action of phosphorus upon air in a large flask, or by means of electricity. It is the source of that remarkable odour perceived when a large electrifying machine is at work, and still more strongly near the spot where a flash of lightning has just fallen. It is a powerful oxidizing agent, and discharges vegetable colours.

CHLORINE AND OXYGEN.

These two elements have but a very slight natural affinity, but by indirect means they may be induced to form five compounds, all of them unstable, and most very explosive. These are *hypochlorous acid*, $Cl\,O$; *chlorous acid*, $Cl\,O^3$; *hypochloric acid*, $Cl\,O^4$; *chloric acid*, $Cl\,O^5$; and *perchloric acid*, $Cl\,O^7$. The fumes of the latter ignite paper. Great caution is necessary in experimenting with all.

CHLORINE AND HYDROGEN.

Hydrochloric acid, $H\,Cl$.—Equal volumes of hydrogen and chlorine, mixed together, and placed in the sun's rays, unite with explosion, developing heat and light. This gas is commonly prepared by gradually heating common salt along with oil of vitriol, and collecting the product over mercury. It is a colourless, irrespirable, incombustible gas, of suffocating odour, and strongly acid reaction. It fumes in moist air, and with ammoniacal gas it forms dense white clouds. By pressure and cold it may be condensed to a colourless fluid. The gas is rapidly absorbed by water, forming aqueous hydrochloric or muriatic acid, which possesses the odour, taste, and acid properties of the gas. It is prepared on the large scale by heating common salt and sulphuric acid in horizontal iron cylinders, and receiving the gas in a series of bottles containing water, joined together by bent tubes. It is also obtained as a secondary product in the manufacture of soda.

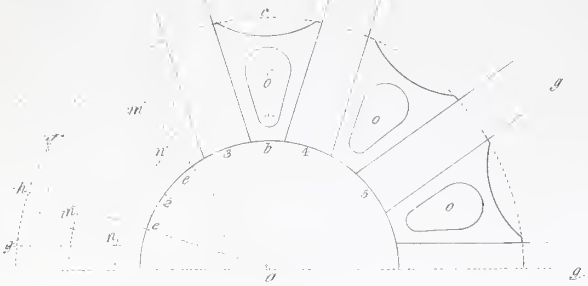
CHLORINE AND NITROGEN.

If chlorine gas is passed through a solution of sal-ammoniac, at 46° F., a film collects upon the surface, which finally sinks to the bottom of the vessel like oily drops. These are *terchloride* of nitrogen, the most dangerous explosive known. It is decomposed with fearful violence by an elevated temperature, and by contact with phosphorus and all greasy or oily bodies. A portion, no larger than a mustard-seed, placed upon a flat earthen plate in the open air, and exploded, not only shivers the plate to pieces, but drives many of the fragments into the ground.

It may be here not inappropriate to give a brief view of the nature of explosion, and of explosive bodies in general. Explosion consists in the instantaneous conversion of a solid or liquid body into the gaseous state, and its consequent expansion to a greatly increased volume. It differs from evaporation only by its greater rapidity. In fact, if water or other liquids are suddenly brought in contact with a highly-heated surface, vapour is given off with a rapidity almost explosive. The mechanical force of an explosion is owing to the sudden expansion which ensues, and which imparts a violent shock to all neighbouring objects. Those substances, of course, are most liable to explode whose elements are held together by a very slight affinity, and assume the gaseous state on being liberated. Nitrogen, which possesses these qualities in a very high degree, is almost constantly present. Thus we find among explosives the various nitrates, the fulminates, the amidides of gold, silver, and mercury, the chloride, iodide, and bromide of nitrogen, as well as a number of organic nitrogenous bodies. The oxygen compounds of chlorine, which explode with great violence, alone or in company with other bodies, act on the same principle. The explosion of oxygen and hydrogen gas, however, accompanies combination, not decomposition. Of all these bodies, one of the feeblest only, gunpowder, has been generally turned to account. The rest are for the most part too violent and uncertain in their action, exploding sometimes without apparent cause. From some experiments, undertaken by the writer, in order to ascertain the conditions of these so-called spontaneous explosions, he was inclined to believe that chloride of nitrogen might be exploded by the passage of an "electric wave" in the atmosphere.

The compounds of bromine and iodine are in almost every respect analogous to those of chlorine. Both form acid gases with hydrogen, the hydrobromic and hydriodic, and explosive compounds with nitrogen. Their oxygen compounds are more stable than those of chlorine.

MECHANICAL DRAWINGS.



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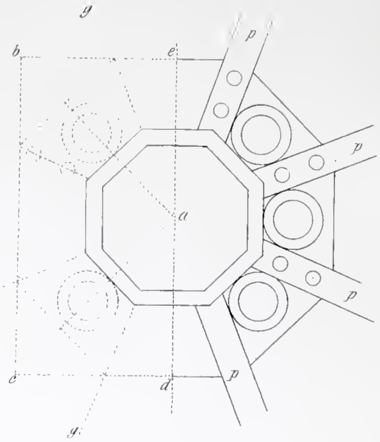

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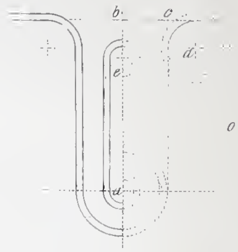

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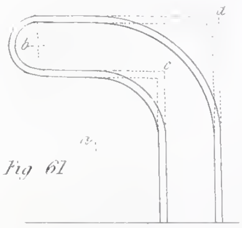

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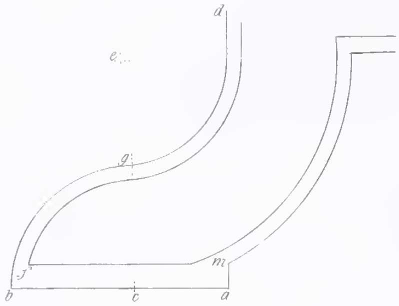

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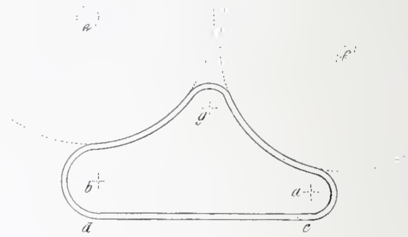

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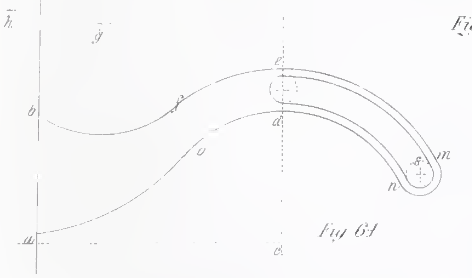

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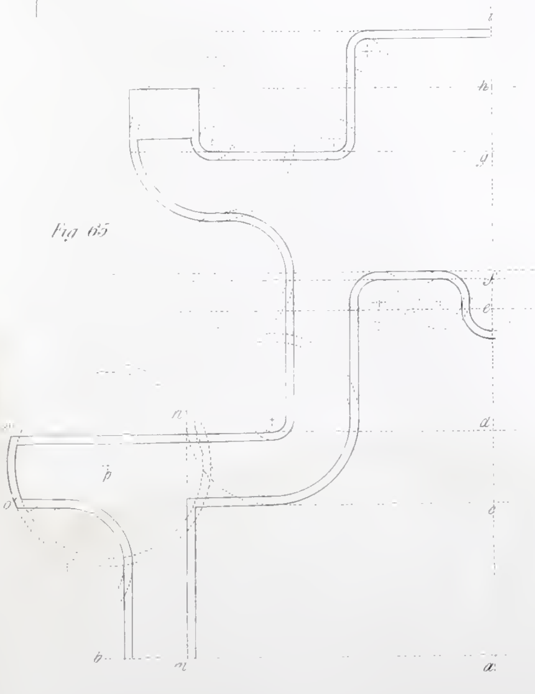

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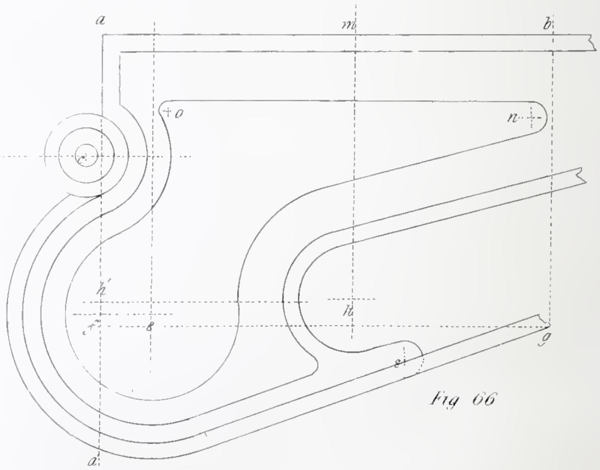

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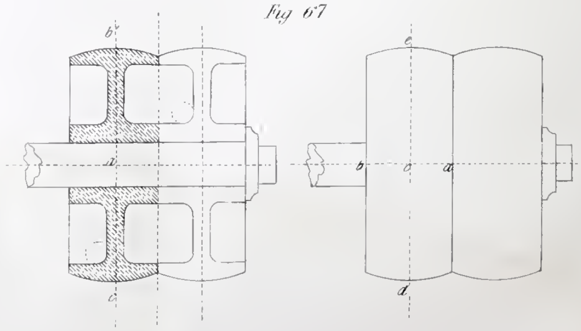

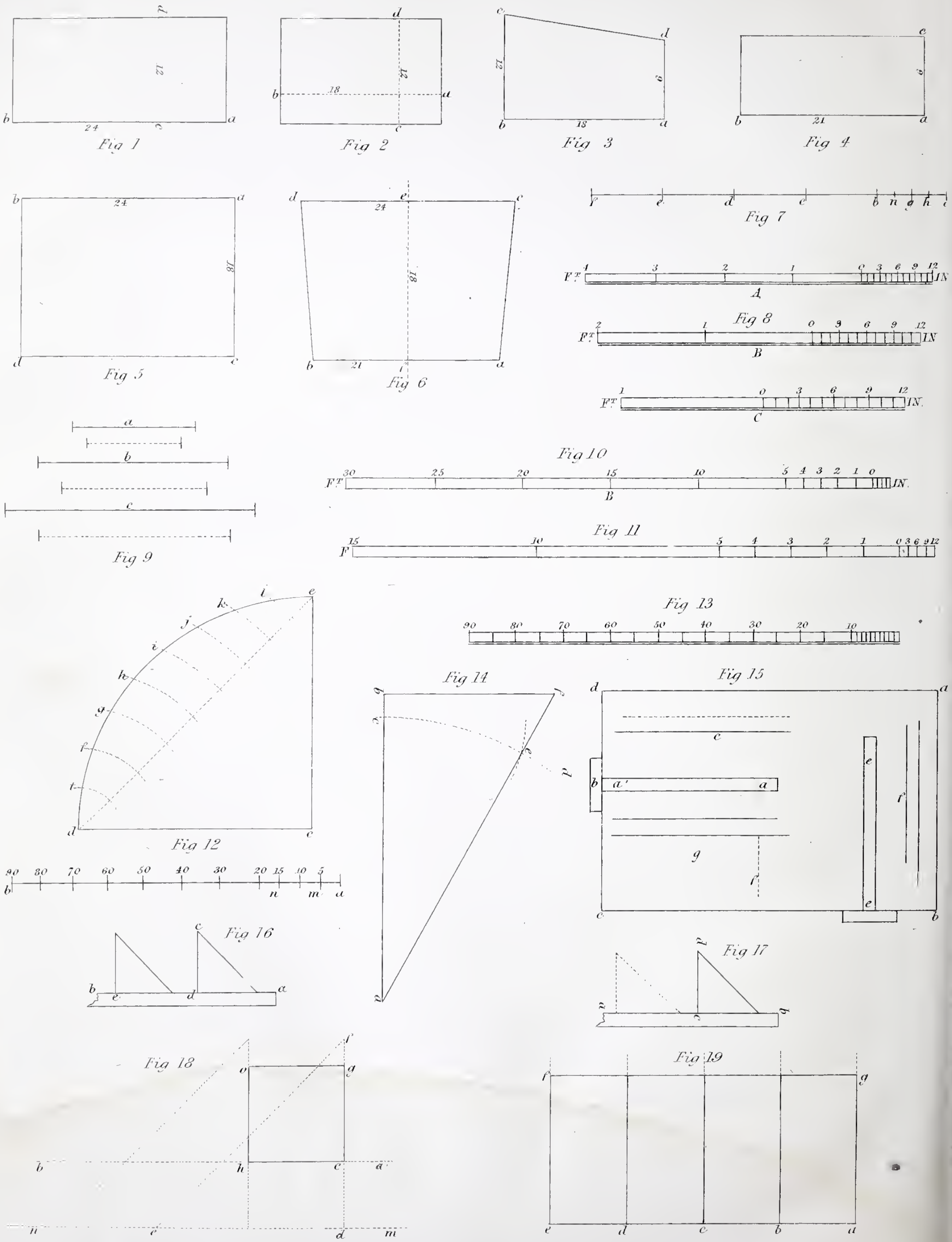
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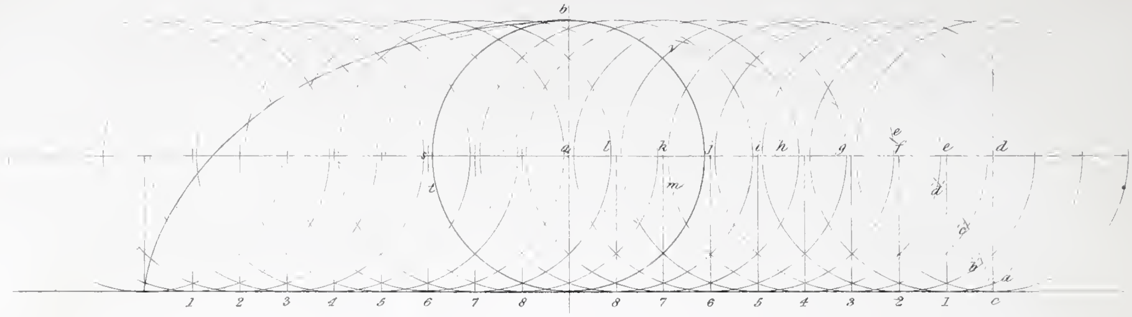

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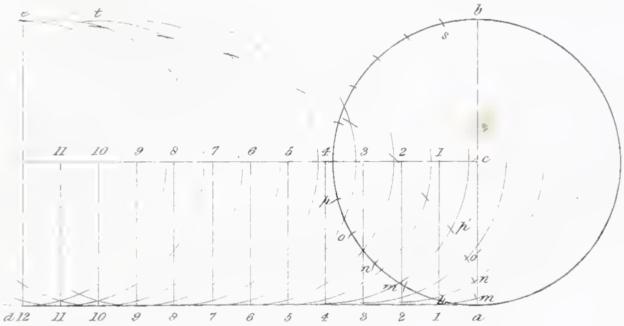

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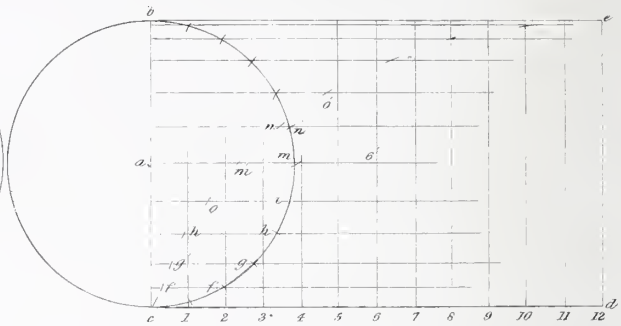

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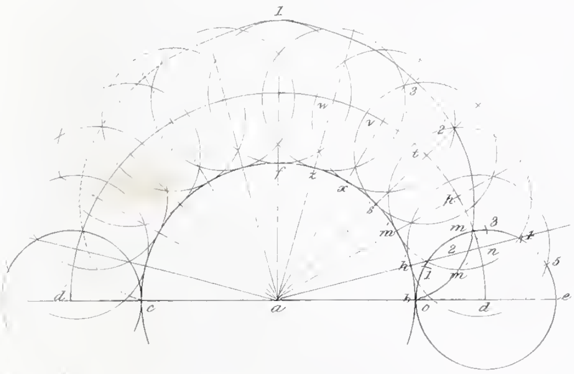

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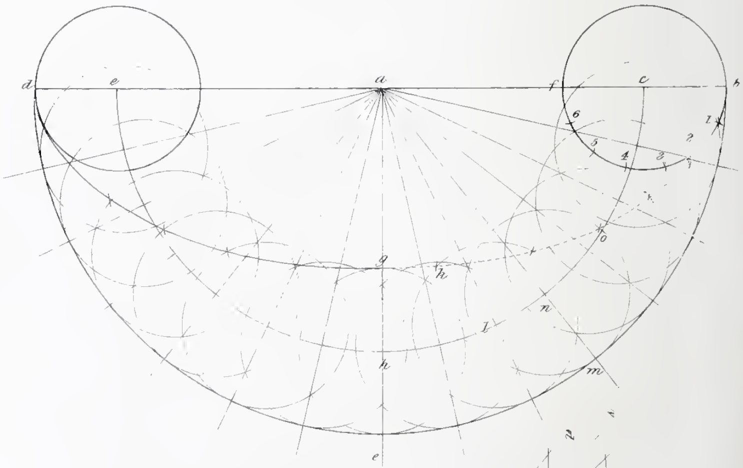

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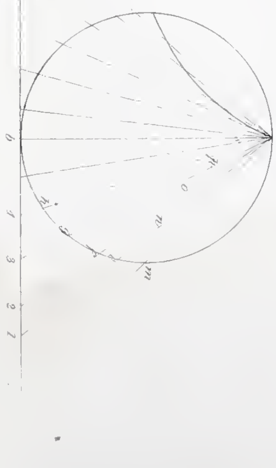

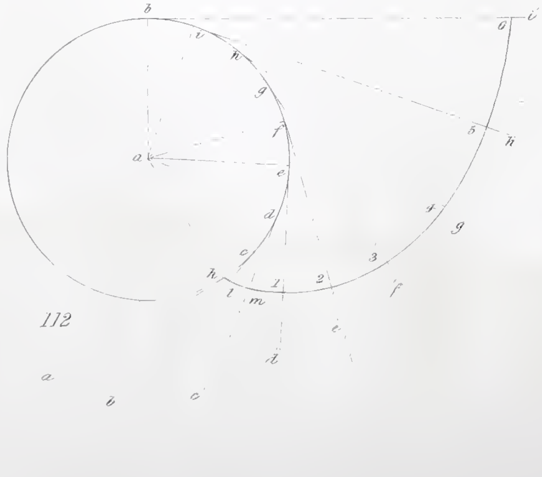

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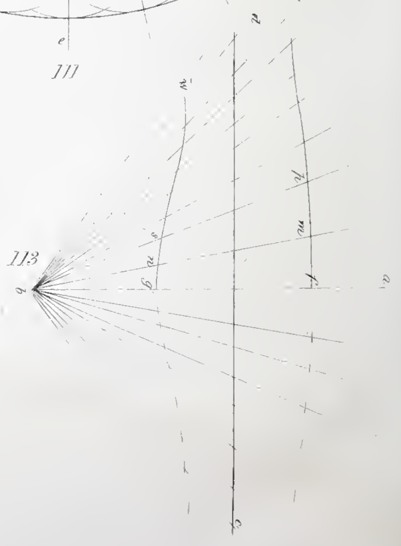

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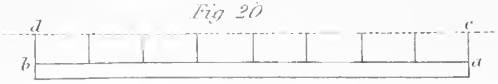

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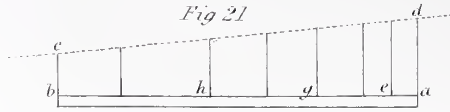

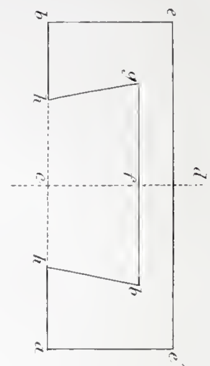
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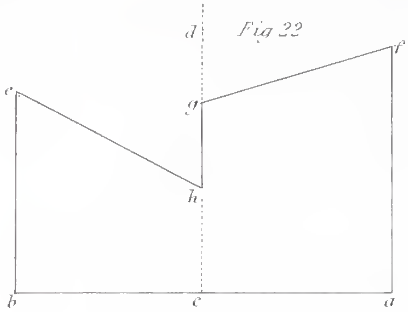

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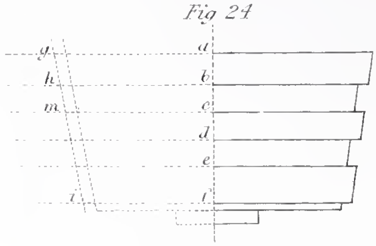

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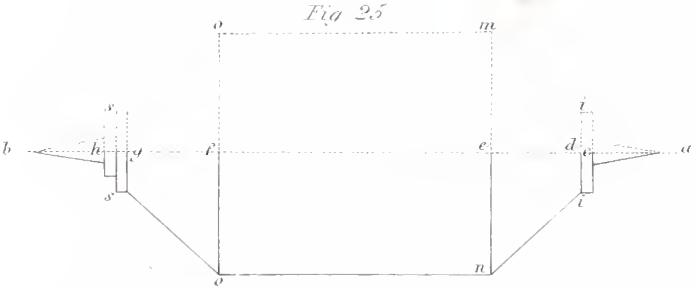

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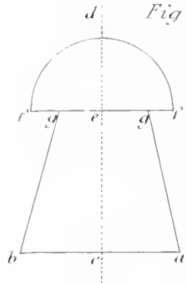

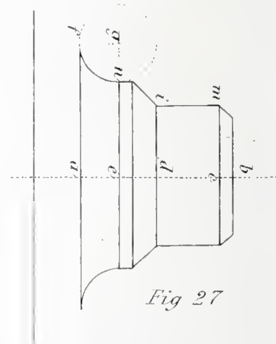
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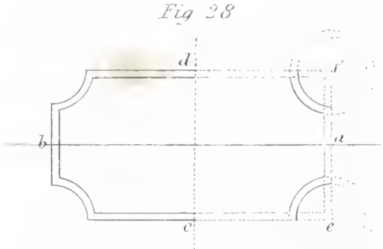

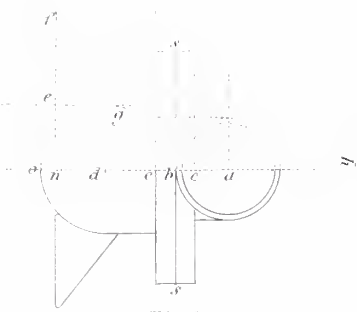
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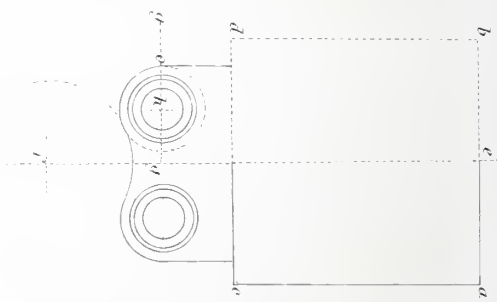
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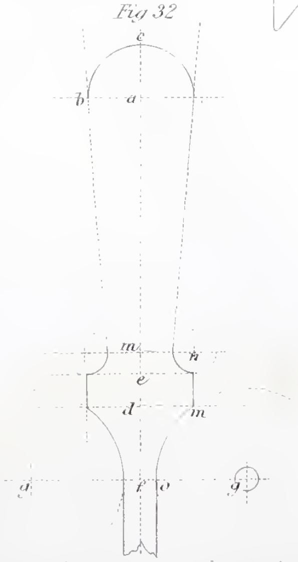

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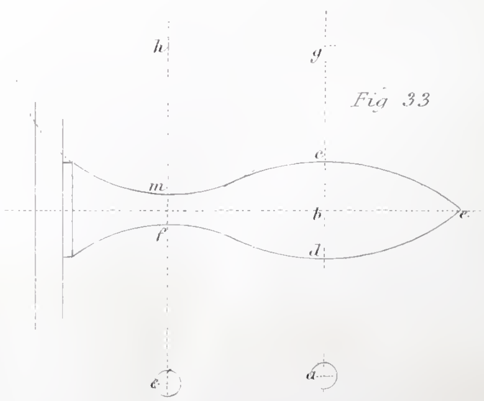


COMPOUNDS OF FLUORINE.

Fluorine is the only element which has not been combined with oxygen. With hydrogen it forms an acid, H F. This is obtained by heating one part of pounded fluor-spar with two parts of oil of vitriol in a retort of lead or platinum. The product is collected in a receiver of the same metals surrounded with ice. It should be preserved in bottles of gold, platinum, lead, or gutta percha.

Hydrofluoric acid is a clear, colourless liquid, of a pungent odour. If it falls upon the skin, it causes dangerous ulcers. It dissolves glass and rock crystal with considerable rapidity. With boron, fluorine forms a gaseous acid, BF^3.

Boracic acid, BO^3, and silicic acid, SiO^2, have been already described (Vol. I., p. 546-7).

ILLUSTRATIONS OF MECHANICAL DRAWING.

CHAPTER VIII.

THE DELINEATION OF MECHANICAL, ARCHITECTURAL, AND ENGINEERING SUBJECTS, AND THE FORMATION OF WORKING DRAWINGS AND PLANS.

Mechanical Drawing may be divided into two branches. In one, the methods are explained by which "projections" of various objects are effected; and of the details of which the three last chapters, in pages 299, 320, and 398, Vol. II., may be taken as introductory. In the second branch, and to which the first four chapters, pages 29, 148, 240, and 349, Vol. I., are introductory, and which we designate by the term constructive, the methods are explained by which are formed combinations of lines and curves, representing outlines of various objects, by means of operations identical in principle with those by which forms and problems, known as *geometrical*, are constructed and laid down on plane surfaces. This style of delineation affords a true representation of the size of the subject, and the relative position of the lines forming it, these being all situated on plane surfaces. An object, however, shown in this way is confined to one point of view; and should another be required, to give the form and dimensions as seen from another point of view, a second delineation must be constructed. Thus, to delineate the various views of a box, of which the length is two feet, depth one foot, and breadth one and a half feet, three delineations or views at the least would be necessary. In the first, a *parallelogram*, two feet long and one foot high, would show the dimensions of one side of the box, and which would be termed the "front elevation." In the second, the view would be represented by another parallelogram, one and a half feet long, by one foot broad or deep; this being termed the "end elevation." The plan of the top, as looked down upon in a direction at right angles to the plane of its surface, would be represented by another parallelogram, two feet one way, by one and a half the other; thus the third view would be termed the "plan." The back elevation and the other end elevation would, in this case, be the same in dimensions as the "front" and "end elevation" respectively. But supposing that an alteration in the shape of the box was made, so as to make the back only one foot nine inches in length, the front being two feet as before; suppose further, that the depth of the box at the back was to be nine inches, that at the front one foot, as in the previous case, four different views will have to be constructed in order to serve as the "working drawings" of the box, instead of three as before. The "front elevation" will be of same dimensions, and be delineated thus:—$a\,b$, fig. 1, Plate I., being the length, two feet; and $c\,d$ the depth, one foot. The "end elevation," however, will not be as in the first instance, as in fig. 2, where $a\ b$ being breadth, one and a half foot, and $c\ d$ depth, one foot; but it will be delineated as in fig. 3, where $a\,b$ is breadth of end, one and a half feet as before; $b\,c$ depth at front, one foot; $a\,d$ depth at back, nine inches. As already noticed in describing the first supposed case, the "back elevation" would be delineated the same way as the front, but being of same dimensions would not be required; in the present instance, however, a view of the "back elevation" would be required as in fig. 4, where $a\,b$ is the length, equal one foot nine inches; the depth $a\,c$, equal nine inches. The "plan," in place of being delineated by a parallelogram, as in fig. 5, where $a\,b$ would be the length, equal two feet, and $a\,c$ the breadth, equal one and a half feet; would be of the form as in fig. 6; $a\,b$ showing the length of front, $c\,d$ length at back, the breadth being represented by line $e\,f$, equal one foot and a half.

Thus, in the first instance, three views would be necessary—"front elevation," "end elevation," and "plan;" while four would be required in the latter, the fourth being termed the "back elevation." By certain methods of delineation, more or less complicated, the three views of the first subject could all be represented in one drawing, or sketch, as by the method adopted in "linear perspective;" but as from the diminution of the lines which recede from the eye of the spectator in accorddance with the laws of vision, great difficulty would be experienced by a workman in ascertaining the size of the various parts of the box, according to any particular scale. Hence, the method of delineating objects in "parallel projection," the nature of which we have endeavoured to describe by a few plain diagrams, is the one which is usually adopted by mechanics and architects, for explaining the outline and dimensions of subjects, the sizes of which it is necessary for the workman to be able easily to ascertain; and this method is found the most convenient, even though so many views of the same subject may have to be constructed.

As the infinite variety of subjects in mechanics, architecture, and engineering, exhibit in their outlines many of the representations of what are known as "geometrical forms," it is evident that a knowledge of geometrical construction, as applicable to the delineation of various outline figures, as squares, hexagons, ellipses, &c., is absolutely essential, and constitutes what may be termed the alphabet of constructive drawing. In pages 27, 148, 240, and 348, of this work, Vol. I., this desideratum has been in some measure supplied. A glance, however, at any of the drawings of mechanical or architectural subjects in the present work, as in the longitudinal section of the West India Mail Packets, constructed by Baird & Co.; or as in the plate of Johnson's Boiler, fig. 1; or Ryder's Forging Machine, fig. 2; or of the Grecian Ionic (orders of architecture), will at once make it evident, that combinations of lines and curves there met with, will require the same precision of arrangement, and accuracy of measurement, which are so necessary in the construction of any of the "geometrical forms," which, in former chapters, have been endeavoured to be elucidated. It is abundantly clear, however, that from the endless variety of combinations which mechanical and architectural subjects present, it would be a serious task to give explanations as to the method by which all of them should be delineated; neither is this task required—a few general applications, showing the method of analyzing the position of lines, and the quickest method of transferring them to paper, will alone be sufficient; leaving it to the reader to construct a system by which he will readily delineate any subject, however complicated.

The value to the mechanic or operative, of a means of copying drawings, or of bringing them down to a correct scale, from his own rough pen-and-ink or pencil sketches, or those of others, with facility, and with something of the accuracy and the method of geometrical construction, is still further enhanced by the fact, that in many of the forms in machinery and of architectural subjects, as much *speciality* of construction is required as in the drawing of a pentagon or hexagon, according to the rules of "practical geometry." The reader, if a mechanic, will meet with many exemplifications of the truth of this in his daily practice; not to extend the list, we may here note the method of delineating the teeth of wheels, of the curved arms of pulleys, &c., and the various mouldings of architectural objects.

From these remarks, the reader will derive some idea of the nature of our further papers, not claiming for them the status due to elaborate articles in the construction of drawings, according to the rules of "projection," by which one drawing may give several views of one object; we may nevertheless look upon them as a medium for conveying information of that degree of value, which will be serviceable to the practical man

in his every-day occupation. It may, however, be advisable to detail the nature of the subjects, of which we propose to treat. Under the first division, we propose explaining the nature and construction of scales; the method of copying various kinds of mechanical subjects, as framing, pulleys, &c.; and the delineation of specific parts of machinery, as screws, teeth of wheels, eccentric curves, &c. In the second division, the delineation of architectural subjects will be described, and the method of drawing the various mouldings, vases, arches, balusters, &c. Under the third division, the delineation of subjects in civil engineering will be entered upon, and the method elucidated of constructing maps and plans, and of the preparation of finished drawings. From these preliminary remarks, the reader will perceive that the contemplated series of "lessons," bear the same relation to the more intricate branches of "projection" of mechanical subjects, that the copying of landscapes (already laid down on paper) bears to the rules of "perspective," by which the direction of the various lines, and their relation to one another, are obtained. But as the ability to copy a complicated landscape, by the adaptation of lessons, by which the habit is inculcated of readily appreciating distances by the eye, and of transferring them accurately to paper, is of use not only in itself, but is absolutely indispensable before the pupil can acquire a practical knowledge of the higher branches of the art; so, in like manner, we conceive that the lessons which we propose giving, will not only impart to the pupil a ready facility in *copying* drawings, but will be highly useful also in assisting him to carry out the higher branches of projection, should he be desirous of having practical acquaintance therewith. A very slight consideration will show the importance to a workman, of being able thereby to copy a drawing quickly and accurately,—this facility of copying being, in fact, what the course of "mechanical drawing," as it is termed, usually gone through at our mechanics' institutes and schools, is designed to impart. Our papers may, therefore, be looked upon as an endeavour to supply, through the medium of letterpress and illustrations, what is communicated orally at our schools.

We now proceed to the consideration of the various divisions of our subjects; and first as to the construction of scales.

The nature and uses of plain scales, adapted to the ordinary standard of measurement by feet and inches, may be easily explained by the following illustration. In explaining the method of drawing the different views of the box in the preliminary portion of our remarks, we supposed that the view of the front elevation was shown by a parallelogram, two feet long by one foot broad. Now it is obvious, that if this was transferred to paper, the inconvenience of the size would be very great; so much so, in fact, as to render this method altogether inapplicable to the purposes of delineation for working drawings. It is obvious, however, that if some arbitrary measurement of a length *much shorter* than an actual foot could be decided upon to represent a foot, that the box or parallelogram could then be delineated on paper, occupying so much less space than before, just in proportion as the measurement decided on to represent each foot of its length was less than an actual foot. But as measurements less than a foot—as inches—are in constant requisition, it is necessary that the measure of an inch be decided on, its length being so much shorter than an actual inch, in proportion as the measure decided on to represent a foot was so much shorter than an actual foot. This proportion between the two arbitrary measures can be at once obtained, by dividing a line equal to that representing one foot, into twelve equal parts, there being twelve inches in one foot; but as there are also eight divisions in an inch, the line representing an inch will have to be divided into eight equal parts. Thus lines denoting feet, inches, and eighths, will have been formed in strict proportion to one another. This is the *rationale* of the construction of a scale; how measurements are taken from scales, and tranferred to paper, will next be explained.

And, first, as to the making of a scale. Suppose a "scale of $\frac{1}{2}$ inch to the foot" is required, take in the compasses the distance of half an inch from an ordinary mechanic's "foot-rule," and lay this any desired number of times along a line, as *a f*, fig. 7; each of the divisions, as *a b*, *c d*, *e f*, represents a "foot." The inches are represented by dividing the last division to the left hand, as *a b*, into twelve equal parts; in small scales, the division points of the third inch as at *n*, the sixth as at *g*, and the ninth as at *h*, are only shown; each of these being assumed to be divided into *three* parts. It will be seen, therefore, that all the divisions to the right denote feet, those to the left inches; the last division to the left invariably denoting inches, divided for this purpose as described. Fig. 8 shows the method of delineating scales; A being that of "one-half inch," B "three-quarters of an inch," and C "one inch," to the foot. In taking measurements to be transferred to paper from a scale, proceed as follows:—Suppose the distance 1 foot 9 inches is desired to be taken, with one foot or point of the compasses in the division marked 1—A, fig. 8—open the compasses until the other leg cuts the point 9 in the last division to the left. To take the distance 1 foot 4 inches, with one point in the point 1, fig. 8, A, open the compasses to the point 4; in both these cases, the distances thus obtained are transferred to any given line required. In fig. 9, *a* represents a line 1 foot 9 inches long, taken from the scale A, fig. 8; *b* the same distance from the scale B, and *c* that from scale C; the dotted line beneath each of these denotes a line representing 1 foot 4 inches, taken from the three scales in fig. 8.

In the laying down of architectural plans, a different style of scale is used; this is delineated in fig. 10, which is a scale of one-eighth inch to the foot. The large divisions to the right all comprise five feet, the last large division to the left being divided into five equal parts, each representing a foot; another or sixth division being added, which being divided into twelve equal spaces denote inches. In constructing a scale in this way, a line is first to be drawn, and the distance having been decided on as quarter of an inch, which is to represent a foot, as in fig. 11; lay off six of these consecutively, divide the last to the left into four equal spaces (or twelve, if the scale is large enough), denoting the points of the 3d, 6th, and 9th inches; then mark the point from the last division 1, the next 2, and so on, denoting the points of the 1st, 2d, 3d, 4th, and 5th feet. Taking the extent of five of these divisions, or five feet, mark them off along the line to as many places as required (an architectural scale should never be shorter than twenty feet); each of these large divisions comprise five feet, and have to be numbered as in the sketch, denoting the points of the 15th, 20th, and 25th foot, and so on. To take the distance of, say, 5 feet 9 inches from this scale, put one point of the compasses in the division 5, and extend the other to the division 9 in the last division to the left, the distance thus obtained will be that required. To take 15 feet 6 inches, place one point in the division marked 15, the other in 6, and the distance will be that required. We have thus explained the nature and construction of scales, too minutely as some may deem; but we, in a series of lessons such as the present, think the best and the quickest way in the end is thoroughly to explain the foundation processes of an art, although these, undoubtedly, are as "familiar as household words" to the educated. The supposition we hold is, that our readers are presumed to know nothing whatever of the art, and are desirous of learning its rudiments. Where these are mastered, there need be no difficulty on the part of the reader in carrying out processes afterwards, of any degree of complexity. The preliminary knowledge being once obtained, patience, perseverance, and practice will effect all the proficiency desired.

In the delineation of mechanical and engineering subjects, angles of certain extent are sometimes required to be laid down. This process is effected by what is termed a "scale of chords," and which is constructed as follows:—Draw any line *c d*, fig. 12, and from *c* describe a quadrant of a circle *d e*, joining a perpendicular carried up from *c*. Divide the arc *d e* into nine equal parts—as in the diagram. From *d*, with *d t* in the compasses, transfer the distance *d t* to the line *a b*; this comprises 10 degrees; with *d f* to the point 20, from *a* on the line *a b*, with *d g* from *a* to the point 30, and so on; with *d h*, *d i*, *d j*, *d k*, *d l*, and *d e*, to the points 40, 50, 60, 70, 80, and to *g*, which is the point 90° on the scale. The spaces thus obtained on the line *a b* may be divided into two parts, each denoting the position of the 5th degree, as in *m n*, the 5th and 15th points.

In fig. 13, "a scale of chords," as generally delineated, is given; all the spaces between the tens being divided into ten equal divisions, each denoting a degree. In page 299, Vol. I., a useful appendage to the drawing implements is delineated in fig. 5, and is there described as a triangle of 60 and 30 degrees. Fig. 14 is designed, not only to show the method of constructing this implement, but also to explain the method of using the scale of chords. Draw any line, *a b*; take the distance of 60 degrees, fig. 13, in the compasses, and with it, from the point *a*, fig. 14, describe an arc *c d*; with the distance of 30° in the compasses, mark off *a* on the arc *c d*, from *c* to *e*; from *a*, through this point, draw a line *a e*, and continue it any distance beyond *e* as required, according as the triangle is required long or short, the line *b f* is drawn perpendicular to *a b*, either within or without the point *c*; the angle *b a f* is 30°, the angle *b f a* 60°.

In pursuance of our plan of beginning with the simplest lessons, an acquaintance with which will form the best foundation for extended practice, we now proceed to the consideration of some preliminary points. In page 28, Vol. I., the various terms, perpendicular, &c. are described, and in the same chapter the methods of erecting perpendiculars, &c., are plainly illustrated. Fig. 15 is intended to illustrate the method of drawing lines perpendicular and parallel to each other, by means of the drawing board and square, as described in page 298, Vol. I.: *a b c d* is the board, best made of plane (lime) tree, or bay wood, with cross pieces at the end, tongued and grooved to prevent the body of the board warping. Lines parallel to one another may be drawn by placing the squares as in the sketch, and drawing lines along its edge, through the various points through which the parallel lines are required; the line nearest the top of the board, as the line *a d*, should be drawn first, moving the square down towards the lower side, or that next to the draughtsman, making the edge coincide with the various points as required; all lines drawn when the square is placed as at *a′ a′*, are said to be parallel to the long way of the board, and at right angles to the short, as *c d*. In drawing a number of lines parallel to one another, when the direction of the square is as at *e e*, the line nearest the right-hand end of the board, as *d c*, should be drawn first, moving the square along towards the end *a b*, as each line is drawn, the square being held in the left hand, the right hand pencilling. All lines drawn as *f′* are said to be parallel with the ends *a b*, *c d*, and at right angles with the side of the board *a d*, *b c*. When one line is required to be drawn at right angles to another, as the line *f* to *g*, the line *g* is drawn along the edge of the square when it is in the position shown at *a′ a′*; the square is next moved into the position as at *c e*, and the line *f* is then drawn along its edge, which will be thus at right angles to *g*. When the direction of lines have to be changed very frequently, it is obvious that, to move the square each time one line is required at right angles to another, would involve much loss of time. This is obviated by using the triangles in figs. 4, 5, p. 289, or fig. 14 in this article, as shown in fig. 16. Suppose *a b* to be the blade of the square, which is used in drawing lines parallel to the sides of the board, and that lines are required to be drawn at right angles to *a b* in the points *d e*, the triangle is placed as in the sketch, and the lines drawn along the end as *d c*. When the square is placed in *e e*, fig. 15, lines at right angles to it may be drawn by placing the triangle as in fig. 17.

In p. 30, Vol. I., we have described the geometrical method of describing a square. In fig. 18 we show the method of constructing one by means of the drawing board, square, and triangle. Let *m n* represent the edge of the drawing square, and *a b* the line on which the given square is to be constructed; let *c* be the point in the line at which one corner of the square is situated. Take the triangle represented by the dotted lines *f d e*; and let its side *d e* be placed against the edge of the square blade *m n*; make the side *d f* coincide with the point *c* on the line *a b*; draw along the edge *d e* any line *c f*; this will be at right angles to *a b*. Let *c g* be equal to the side of square; from *c*, with *c g* in the compasses, mark off on the line *c f* the distance *c g*; from *c* mark off same distance on line *a b* to the point *h*; move the triangle so as to make the side *d f* coincide with the point *h*; and draw along its edge the line *h o*; remove the triangle, and slide the square along the drawing board until its edge *m n* coincide with the point *g*; draw along its edge the line *g o* parallel to *a b*; *c g o h* is the square required. To draw the parallelogram, *a g f c*, fig. 19, with the division lines as marked, make the edge of the square coincide with the point *a*, and draw along it the line *a e*, with the distance *a e* in the compasses; mark off the length *a c* in the line thus drawn; move the square down, so as to make its edge a little below the line *a e*, just drawn. On the edge of the square, place the side of the triangle *d c*, fig. 18, and with its edge coinciding with the point *a* on the line *a e*, draw along its edge *d f* the line *a g*; move the triangle to the point *e*, and along its edge *d f* draw the line *e f*. With one point of the compasses in the point *a*, extend the other leg to the point *b*; with this distance in the compasses, measure from the point *a* (in the copy) to the point *b* on the line *a e*; take in like manner, and transfer the distances *a c* and *a d* to the line *a e*. Make the edge *d f* of the triangle (fig. 18) coincide with the points *b*, *c*, and *d*, and along the edge *d f* draw the lines as in the diagram, parallel to the lines *a g*, *e f*. Next, with the distance *a g* in the compasses, from the point *a* lay off on the line *a g* to *g*; move the square upwards until the edge coincide with the point *g*, and along it draw the line *g f*. The diagram in fig. 20, representing a series of pins projecting from the part *a b*, is constructed in the same manner as the last, the height of the pins being made uniform, by drawing a line *c d* parallel to *a b*, at the proper distance from *a b*, so as to give the desired height to the pins; this line, dotted in the diagram, is not inked in, in making the copy; but is to be rubbed out when the other parts are inked. The diagram in fig. 21 is a modification of last lesson; the pins in this case, however, being unequal in their length, and at unequal distances from each other, as *e g h*, the height of the pin is regulated by measuring from the line *a b* on the vertical lines *a d*, *b c*, to the points *c d*; and drawing the line *d c*, represented dotted, which denotes that it is not to be inked, but rubbed out on finishing the diagram.

We now come to the construction of diagrams in which the use of "centre lines" is exemplified. The nature of these lines will best be understood by an examination of our various examples. To construct the diagram in fig. 22: Draw along the edge of the square any line, as *a b*; assume any point *c*, make the edge *d f*, fig. 18, of the triangle coincide with this point, and draw along it any line, *c d*. From the point *c* with half *a b* taken from the copy, lay off on the line *a b* to the points *a b*; make the edge *d f* of the triangle coincide with the points, and along it draw the lines *a f*, *b e*, parallel to the centre line *c d*. Measure the distances *a f*, *b e*; and set them off on the line *a f*, *b e*; with one leg of the compasses in the point *c*, extend the other to the point *h*; transfer this to the copy; do the same with the distance *c g*; make the edge of the triangle coincide with the points *c h*, and draw the line *e h*, touching *c d*; do the same at the points *f g*, and draw *f g*. In drawing the diagram in fig. 23, the use of the centre line is even more obvious: Draw any line *a b*, assume any point *c*, and by means of the triangle draw the centre line *c d*; with half *a b*, from the point *c*, mark off to the points *a b*, from *a b* draw lines parallel to *c d*, along the edge of the triangle *d f*, (fig. 18), the edge coinciding with the points *a b*. With the distance *a e* from *a b*, mark off to *e e′*; and making the edge of the square coincide with the point *e*, draw the line *e e′* parallel to the line *a b*. From *c*, with half the distance of *h h*, mark off on the line *a b* to *h h*; from *c* measure to *f*, and on the line *c d* lay this to *f*; make the edge of the square coincide with the point *f*, and draw along it a line parallel to *a b*; with half of *g g*, from the point *f*, mark off to the points *g g*, on the line *g f g*; make one of the edges of the triangle coincide with the points *h g*, and draw the lines *h g*. In the finished drawing where the lines are inked, the dotted lines are left out. It may be necessary here to explain that the diagrams without the dotted lines are the copies from which the learner is to derive his measurements, the dotted lines being here given, in order to illustrate more fully the nature of the operations. In copying the diagram in fig. 23, it will be necessary, before proceeding, to continue a dotted line across the vacant space between *h h*, in order to ascertain the exact point for the centre

line which divides the line *a b* equally into two parts; it is obvious that if this line was not drawn, it would be difficult to bisect accurately the distance between *a b*. The method of using the triangle for drawing lines at right angles to the edge of the square, having been now fully enough explained, we will not, in future descriptions, detail the positions in which the triangle is to be placed, but shall assume that, in all cases where admissible, it will be used as already directed.

To copy the diagram in fig. 24: Draw any line *f i*; and at any point on it, as *f*, another, *f a*, at right angles; from the point *f*, with the distances *f e*, *f d*, *f c*, *f b*, and *f a*, transfer them to the line *f a*. Through each of the points thus obtained, draw lines parallel to the line *f i*. From *a*, with the distance *a g*, mark off on the line *a g* to *g*; and with *f i*, from *f* mark off in *f i* to the point *i*, join *g i*—this will give the line defining the projecting parts; the line defining the other parts is drawn parallel to this; its distance from the points *f a* being obtained, and properly transferred to the lines *a g*, *f i*. In this diagram, as in others which we purpose giving, one half is represented finished, and the other in dotted lines; the latter shows the method of operation; but the reader is to understand that, in copying the diagram, the operations are to be carried out on both sides of the centre line *f a*.

To copy the diagram in fig. 25: Draw the line *a b*; assume any point *e*, with distance *e f*; from *e* mark off in the line *a b* to *f*; and through these points draw lines as *m e n*; from *e*, with half the distance *m n*, mark off in the line *m n* to *m n*; from *m n*, parallel to the line *a b*, draw lines *m o*, *n o*, joining *o f o*. From *f* measure to *g*, and from *e* to *d*; through those parallel to *m n* draw lines; with half of the line *i i*, from *d* mark off on the line *d* to *i i*; from *d* mark to *c*, and through *c* draw a line parallel to *d i i*; from *i i* draw short lines parallel to the line *a b*. Put in the parts at *g h*, by the same process; join *m i*, *n i*, *o s*, *o s*, and put in the pointed parts at *a b*.

We now come to the construction of diagrams in which circular lines are met with, as in fig. 26: Draw any line *a b*, and another *c d* at right angles to it; with half of *a b*, from *c* mark off to *a b* on the line *a b*; from *c* mark off on *c d* to the point *e*; through this draw parallel to *a b* a line *e f*; from *e*, with *e f* as radius, describe a semicircle *d f f*; from *e* with *c g* mark off on the line *f f* to *g g*; join *a g*, *b g*.

In copying fig. 27: Draw two lines *a b*, *a f*; with half of *a f*, set off from *a* on both sides of *a b*, as to *f*, take the distances *a e*, *a d*, *a c*, and *a b*, and transfer them from *a* towards *b* on the line *a b*. Through these points draw lines parallel to *a f*; with half of the various lines taken from the copy, set off from *b*, *c*, *d*, and *e* on both sides of *a b*, as from *c* to *m*, *d* to *i*, *e* to *n*; continue the line *c n* towards *g*, with the distance *a e* set off from *n* to *g*; from *g* as a centre, describe the quadrant *g h f*. The angular parts at *m* are put in by means of the "right-angled triangle." (Fig. 14.)

The diagram in fig. 28 is a parallelogram, of which the corners are cut off with quadrants of circles. In copying this, draw two lines *d c*, *a b*; put in the parallelogram, of which half the length is from *f* to *d*, and the breadth from *f* to *e*. The centres of the quadrants will be at the corners, as *e f*; the radius of each circle being half the diameter of the circle at *e f*.

To copy the diagram in fig. 29: Draw the line *a d*; from *a* as a centre, with *a b* as radius, describe the circle *a b*; from *b* mark off to *c c*; through *c b c* draw lines at right angles to *a d*; from *c* measure to *d*, and with *d o* describe the semicircle *d o g*; join the extremities of this with lines parallel to *a d*, to the line *c s s*; from *b* measure to *s s*, and put in the ends of the flange parallel to *a d*; from *d* measure to *n*, and through *n* draw a line as *n f*, parallel to *b s*; from *n* measure to *f*, and from same point to *e*; measure from *e* to *g*, join *g f*.

In copying fig. 30: First construct a square *a b c d*; bisect the side *a b* in *e*, and draw *e f* parallel to *b d*; from *e* measure to *g*, and through this point draw a line *g g* parallel to *c d*; from *g* set off on both sides of *e g* to *h*; and from this point, with *n o* as radius, describe the semicircle *n o g*, and the interior circles as in the drawing; from *g* set off on *c f* to the point *f*; from this as a centre, by an arc of a circle, join the two semicircles; finish as in the drawing.

VENTILATION OF APARTMENTS IN DWELLING-HOUSES.

CHAPTER I.

IMPORTANCE OF THE SUBJECT—THEORY AND PRINCIPLES.

It is somewhat surprising, that one of the elements most essential to the health and happiness of the human family, has attracted less attention—or that whatever attention it has attracted has been less practically attended to—than almost any other element which the *genus homo* requires for its fair development and full preservation. We refer to the inattention which society, as a whole, gives to the due administration of a proper supply of pure air to its own lungs. The subject of ventilation has engaged the attention of many eminent minds, and much has been written on the subject, not only exposing the deadly effects of a vitiated atmosphere, but pointing out the means by which the pure ocean of air surrounding our globe may be made to purify the most densely-peopled districts, and expel the pestilential vapours generated in those parts of our manufacturing cities, where poverty, ignorance, and vice crush portions of society into a rank, festering mass of disease. Nay more, sufficient has been laid before the world to demonstrate, that the insidious evils attendant upon a "splendid crush" at an aristocratic assembly, or the confined cesspools in the hearts of our cities, are alike pestilential, and exhibit the most gross ignorance and carelessness towards the health of the community.

When we hear it spoken, of emigrating to the wild or thinly-peopled districts of Canada, or to the marshy shores of Galveston Bay, or to the pestiferous settlements on the west coast of Africa, or to the many other portions of the world where disease and death meet the unfortunates who venture there, people are apt to reflect, and they do cry out, "Those places are unhealthy!" But if it was generally known and thoroughly understood, that in those portions of our cities where poverty packs human beings in damp, dark, dirty, and confined habitations, the same deadly causes of death originate; if it was generally known and properly understood, that we have the same warm, sickening, steamy vapours of putrefying organic matter arising from our open drains and sewers—the same stupifying effluvia generated in our manufactories and workshops, in back courts, underground hovels, and pent-up lanes—if these things were known, the same feeling which deters people from emigrating to foreign places where fatal diseases are known to be rife, would arouse more attention to our condition at home, and the public voice and the public will would force a radical improvement in the present defective system of ventilation, which predominates to an almost incredible extent amongst all classes of society.

The abundance in which pure air exists throughout all nature may have blunted human perception as to the importance of human beings inhaling it in an unvitiated state, and the easy access which mankind have to this great blessing, may have induced a disposition of carelessness; otherwise, it is difficult to account for the almost universal violation of the laws of nature, observable in the non-ventilation of our habitations, places of employment, and public streets. We may safely aver that the subject of ventilation is only understood by few. And although of paramount importance to the health and happiness of the community, it has neither attracted that public attention nor received that legislative assistance which its utility demands. Nor can it be expected that any great improvement will take place until a thorough knowledge of the subject is engraven upon the minds of all classes of society.

With a view to assist the reader, desirous of becoming acquainted with the subject, in acquiring a knowledge of the theory of ventilation, in order to carry it out into practice, we purpose drawing together a few remarks and illustrations on this important department of sanitary economy.

The usually accepted theory on which the practice of all ventilation is founded is simple, and may be briefly stated. The atmosphere which surrounds our globe is composed of

nitrogen and oxygen, the portion being one of the latter to four of the former; to these may be added a small proportion of carbonic acid gas, and aqueous vapour. The correct proportions, however, may here be stated—oxygen, 27·2 per cent., nitrogen, 75·5 per cent., carbonic acid gas, 1·5 per cent.; the quantity of aqueous vapour varies according to circumstances. By the act of inspiration, the air—which we suppose to be pure, constituted as above—is drawn through the windpipe to the lungs; it there acts upon the blood which is supplied to the minute vessels of the lungs by the veins; imparting its oxygen, and receiving in place of it various impurities, principally carbonic acid gas, which are taken up by the blood in its passage through the body. The air, thus deteriorated, is expelled from the lungs by the muscular action of the chest, and is composed of the same quantity of nitrogen as before, namely, 75½ per cent.; the amount of carbonic acid gas is, however, increased 8 or 9 times, and that of the oxygen decreased nearly one-half. Air that contains 3½ per cent. of carbonic acid gas, is incapable of supporting life; but air expelled from the lungs contains 2·4 per cent.—thus showing the necessity that exists for getting rid of deteriorated air. The quantity of air inspired per minute, varies according to circumstances. The average number of inspirations is usually taken at 20 per minute; and calculating the quantity of air drawn into the lungs at each time at 40 cubic inches, the amount inhaled per minute is 800 inches; 720, 600, and 400 cubic inches have, however, been assumed as the quantity inhaled per minute by a healthy man, by various authorities. On the assumption that 600 cubic inches is the quantity; by the expiration of this from the lungs in a deteriorated state, it is calculated that 1400 cubic inches are rendered unfit for breathing per minute. It is not only by the medium of the lungs that air is deteriorated; through the minute pores of the skin, the air exerts an influence upon the blood, and is exhaled in vapour imperceptible to the eye. It has been estimated, that the amount of vapour exhaled per minute from the body, varies from 30 to 45 grains. The change, then, that air undergoes, whether acted upon by the medium of the lungs or that of insensible perspiration, is that from a healthy to an unhealthy—from a life-supporting to a life-destroying principle. The process of respiration is essentially the same as that of combustion; the two, so apparently dissimilar, are in fact identical. Life is a slow combustion. Liebig estimates that 14 ounces of charcoal is burned daily within the body. The food we partake of is converted into blood, which contains hydrogen and carbon; the combustion of these is produced by the combination of the carbon of the blood, with the oxygen of the air inhaled into the lungs. The only difference between the combustion of any noticeable and obvious kind, as that of a fire or candle, and that of the various component parts of the human body, is, that in the latter the process is carried on much more slowly, yet not the less certainly. The air thus deteriorated by the process of respiration or combustion of the human body, is that which, when collected in apartments of our dwelling-houses, or places of public resort or entertainment, it is the duty of an efficient system of ventilation to remove. The air in ordinary apartments is also much deteriorated by the combustion of gas and candles—one of the latter consuming nearly as much air per minute as a man.*

The theory above explained, and so generally admitted, is correct so far as it goes; nevertheless, it does not account for various phenomena which are observable in close examination of the dwelling-places of man, especially in crowded towns and cities. According to the notions of chemists and philosphers, who have been contented with the results of mere observations in the laboratory, rather than in those of extended observation and research, the constitution of the air in crowded towns or confined situations does not differ from that obtained in the open country. "Most men would be satisfied of the impurity of an atmosphere through which a blue sky could never be seen of a blue colour, or where a bright cloud appears of a dingy-brown; but there are men who take this air into glass receivers, and, because they detect no new substances or strange compounds, they deny that there is any peculiarity. . . . . . This seems to be only a proof that men, accustomed to experimental inquiry, are apt to forget the value and force to be attached to those apparently less rigorous observations which the senses are constantly and unconsciously making, and to believe only that which can be demonstrated by the grosser processes of a laboratory." That the general and popular view of the matter is opposed to this philosophical view, a moment's consideration will at once show. There is certainly something which makes men prefer the country air, that, trembling,

> "Floats from hill to hill—
> From vale to mountain—with incessant change
> Of purest element"—

to that which, in crowded towns,

> "From a thousand lungs, reeks back to thine,
> Sated with exhalations rank and fell."

That this general feeling is in reality an exponent of one important truth, or is an evidence of its existence, will be clear from the following extract from a Report to the General Board of Health, on the "Air and Water of Towns," by Dr. Angus Smith, a gentleman who has contributed largely to the store of practical facts in connection with the science of sanitary economy. By this extract, the reader will perceive that experiment and research have made clear, what was long suspected, that, in addition to the chemical change undergone by air through the process of respiration, there is another cause of contamination, in the presence of an appreciable organic substance of a highly poisonous nature:—"The air has often been called a general receptacle for all impurity; nature has made it a universal purifier, by giving so large an amount of free oxygen. It is oxygen which purifies, and bodies which are impure have a tendency to volatilize, after which they become pure. No doubt, the air of a town contains a portion of all exhalations which arise in a town. There are such as come from living bodies, in the first instance—exhalations which can never be got rid of, but which, it is probable, are not at all dangerous unless accumulated. There are also exhalations from the refuse matter of animals, and from combustion of fuel. These are the chief points. Various manufactures give out various effluvia; and no man that has walked through a large town with attention, can have failed to perceive that no street is entirely free from effluvia, and that every one seems to have a peculiarity of its own. The smell is a delicate guide to this; and although custom causes us to forget that odour to which we are much exposed, a frequent change gives us still more acuteness, and both houses and streets may fairly be complained of when the inhabitants are little aware of it. That animals constantly give out a quantity of solid organic matter from the lungs, may readily be proved by breathing through a tube into a bottle, when the liquid, or condensed breath, will be collected at the hottom of the bottle; or by breathing through a tube into water, when a solution of the

* The trials of Leblanc upon vitiated atmospheres are of high interest. The quantity of carbonic acid in the atmosphere in the normal state, has been shown by the Saussures to vary from 3 to 6 parts in 10,000. Leblanc (Ann. de Chim. v. 223) has examined the quantity in crowded rooms, theatres, cities, &c. In the hospital La Pitie, the air of one of the wards, containing 54 patients, afforded $\frac{3}{1000}$ of carbonic acid, that is, 5 times more than that of normal air. Under similar circumstances, at the Salpetriere, the quantity was $\frac{8}{1000}$. In Dumas' class room, after a lecture of an hour and a half, where 900 persons were present, the carbonic acid amounted to 1 per cent., and the same quantity of oxygen had disappeared. From other experiments, he considers this a maximum quantity for safety, and strongly recommends a better ventilation when so much carbonic acid is present. This result agrees with experiments made in this country. When the atmosphere is deteriorated by burning charcoal, he has seen death produced when 3 per cent. of carbonic acid was present in the atmosphere. In all such cases of death from stoves, he has found carbonic oxide in the air, and he attributes a deleterious effect to the agency of this gas. He has observed 1 per cent. of this gas to destroy an animal in two minutes, which is at variance with the statement of Nysten. This observation explains many of the inconsistencies which appeared some years ago in the evidence of some London chemists respecting the influence of Joyce's stoves. It is quite obvious that their structure was dangerous. Leblanc found that a candle was extinguished in air containing 4½ or 6 per cent. of carbonic acid. In such an atmosphere, life may be kept up for some time, but respiration is oppressive, and the animal is affected with very great uneasiness. Air expired from the lungs contains about 4 per cent. of carbonic acid, and hence this atmosphere is noxious. Even 3 per cent. in the atmosphere killed birds, and yet we have seen statements which affirmed that upwards of 3 per cent. had been detected in the London theatres. All these facts are pregnant with importance in reference to health. Our miners may not be suffocated by fire-damp explosions, but we should remember that their constitutions may be poisoned by the respiration of tainted atmospheres.—*Proceedings of the Glasgow Philosophical Society*, 1841-42.

same substance will be found in the water, This would scarcely require proof, if we considered that breath has so frequently an organic smell—perhaps, rather, it has always an organic smell; and when it is bad, the smell is often offensive, containing decomposing organic matter.

If this condensed breath be put on a piece of platinum, or on a piece of white porcelain, and burnt, the charcoal which remains, and the smell of organic matter, will be conclusive. If it be allowed to stand a few days (a week is enough), it will then show itself more decidedly, by becoming the abode of small animals. These are rather to be styled animalcules, and very small ones certainly, unless a considerable quantity of liquid be obtained; they may be seen with a good microscope. Animalcules are now generally believed to come from the atmosphere, and to deposit themselves on convenient feeding places; that is, they only appear where there is food or material for their growth, and they prove, of course, the existence of that continuation of elements necessary for organic life. At the same time, their presence is a proof of decomposing matter, as their production is one of the various ways in which organized structures may be broken up. Such a liquid must, of course, be an injurious substance, giving out constantly vapours of an unwholesome kind.

I mentioned, some time ago, that I had got a quantity of organic matter from the window of a crowded room, and I have since frequently repeated the experiment. This matter condenses on the glass and walls in cold weather, and may be taken up by means of a pipette. If allowed to stand some time, it forms a thick apparently glutinous mass; but when this is examined by a microscope, it is seen to be a closely matted confervoid growth; or, in other words, the organic matter is converted into confervæ, as it probably would have been converted into any kind of vegetation that happened to take root. Between the stalks of these confervæ are to be seen a number of greenish globules, constantly moving about various species of volvox, accompanied also by monads many times smaller. When this happens, the scene is certainly lively, and the sight beautiful; but before this occurs, the odour of perspiration may be distinctly perceived, especially if the vessel containing the liquid be placed in boiling water.

When this exhalation from animals is condensed on a cold body, it in course of time dries up, and leaves a somewhat glutinous organic plaster; we often see a substance of this nature on the furniture of dirty houses, and in this case there is always a disagreeable smell perceptible. I have no doubt that this is a great cause of the necessity for constant cleaning, which experience has found, and made to be a very general practice in England and elsewhere. In other words, it is a reason why that which is not cleaned becomes dirty—a question which I have often felt great difficulty in answering.

Water is necessary to the spontaneous decomposition of animal matter, and it is probable that, in a warm climate, this coating of walls and furniture would not be so dangerous as with us, where everything is exposed to moisture a considerable part of the year. In a warmer climate, it will probably be diffused into the atmosphere, and not be so much retained as it is by the moisture which dissolves it, or to which it attaches itself.

It will probably be found that this substance is not poisonous, if taken into the stomach; but it is known to be poisonous breathed into the lungs, as we know crowded rooms are. The quantity is small that we do breathe, but at the same we must remember that it is diffused in air, and has, therefore, a surface as extended as the volume of the air in all probability; and we know that a cubic inch of sulphuretted hydrogen will scent at least some hundred cubic feet of air."

The following is a summary of the results of Dr. Smith's investigations on this important point:—

1st, That the pollution of the air in crowded rooms is really owing to organic matter, not merely carbonic acid.

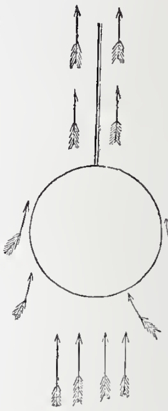
2d, That this may be collected from the lungs or breath, and from crowded rooms indifferently.

3d, That it is capable of decomposition, and becomes attached to bodies in an apartment, where it probably decomposes, especially when moisture assists it.

4th, That this matter has a strong animal smell, first of perspiration, and, when burnt, of compounds of protein, and that its power of supporting the life of animalcules proves it to contain the usual elements of organized life.

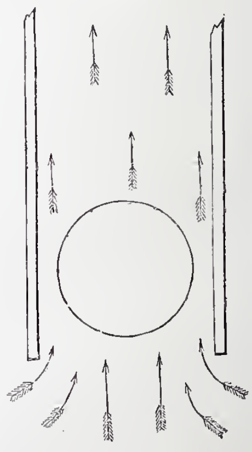
Another property of the atmosphere, recently discovered by Schönbein, the inventor of gun-cotton, is that known as *ozone*. Schönbein found that by decomposing water by electricity, or by allowing phosphorus to act on moist air, a substance was produced, and which, from its having a peculiarly strong odour, was called ozone. Ozone possesses bleaching properties similar to chlorine. Iodide of potassium is decomposed by it. Hence arises a simple method of testing the amount of ozone in the atmosphere. A quantity of iodide of potassium is exposed to the common air, and is mixed with a quantity of starch. The iodide of potassium is decomposed by the ozone supposed to be existing in the atmosphere, and the iodine is liberated; the quantity of this being estimated by the intensity of the blue colour produced in the solution of the starch. The ozone is said to vary in quantity in the atmosphere at different times. Sulphuretted hydrogen decomposes it with great facility. The breathing of ozone is said to be prejudicial to health, producing bronchial irritation. Dr. Schönbein found that, during the prevalence of influenza, the quantity of this substance present in the atmosphere was greater than at ordinary times—he found that it increased also during thunder-storms. "The evidence," says an able writer, "of the presence of ozone in the atmosphere is very slender, and the hypothesis of its being the efficient agent in the production of epidemics is entirely gratuitous. The only proof we have of its presence in the atmosphere, is its action upon iodide of potassium. But iodide of potassium is also decomposed by free nitric acid, which is known to be evolved during thunder-storms, and other electric conditions of the atmosphere, which have been found also favourable for the production of ozone. Since, therefore, under the same circumstances, both substances are frequently produced, and since their action upon the iodide of potassium is exactly the same, it is evident that its decomposition cannot be depended upon as a test for detecting the presence, or for estimating the amount, of ozone in the atmosphere, unless the absence of nitric acid has been previously secured."

Fig. 1.



The importance of ventilation, with reference to its influence on the health, cannot be too forcibly dilated upon. From "faults in the construction and management of our houses, many persons are unconsciously doing, in regard to the air they breathe, nearly as fishes would be doing in regard to the water they breathe, if, instead of the pure element of the vast rivers or boundless sea streaming past them, they shut themselves up in holes near the shore filled with water, defiled by their own bodies and from other sources."

Fig. 2.



Having thus briefly detailed the causes of deterioration of air in our dwelling-houses and public buildings, we proceed to explain simple methods by which the air thus deteriorated is removed therefrom. Previous to detailing these, however, we deem it necessary to point out a few preliminary demonstrations:

If we take a vessel of water, in which we place one or two amber beads, and apply heat so as to raise the temperature of the water, we shortly perceive the establishment of a current or set of currents—the portion of water next the bottom of the vessel, nearest the heating medium, rising upwards, the colder portion from the top descending to take its place. If we could imagine the vessel to be filled with air, and watch the process going on after heat was applied to it, we should perceive the same set of currents in existence. Air when heated expands, and rises amidst the surrounding colder air, just as oil rises in water, or the amber bead in heating water. If a red-hot ball, as in fig. 1, could be suspended in the air, the cold air immediately near its surface, receiving by reflection or conduction (see article on "Heating,") a portion of the heat, would become expanded and rise upwards; cold air from the surrounding space would rush in to supply the place of this rising air, and in its turn becoming heated, would rise also—and thus so long as the heat of the cannon-ball remained great enough. This creation of currents is produced by any body giving out heat, as the combustion of a candle, or the heated surface of a close stove in a hall or large room. The velocity of the currents upwards will clearly depend upon the amount of heat imparted to the air, and also on the time in which this heat can be retained. It is evident, that if, immediately on leaving the heated body, the heated particles of ascending air come in contact with particles of other and colder particles, their ascending power will be checked, and the extent to which they would ascend become considerably lessened. Hence is deduced the expediency of retaining the heated particles together, without suffering them to come in contact with the surrounding colder air; and hence also arises the use of chimneys to conduct smoke quickly from fire-places, and of ventiducts, or ventilating flues, for removing foul air from the interior of our dwelling-houses. Thus, if we place the heated cannon-ball at the foot of a flue, as in fig. 2, the upward rush of air in the tube will be greatly accelerated by the particles of the heated air being kept close together, and protected from the influence of the surrounding cold air; and the rush of air towards the ball will thus, in consequence, be much quicker than if no tube or chimney was placed above it, and this from the increased velocity of the heated air in the tube. Air, when expelled from the lungs, has a considerable amount of heat imparted to it, sufficient to give it an upward tendency of a very considerable force. We know that this upward tendency in breathed or deteriorated air, is disputed by some practitioners upon the following grounds:—"Air, when expelled from the lungs, being composed chiefly of carbonic acid gas, the specific gravity of which is more than one half heavier than common air, must necessarily have a descending movement, and fall towards the ground." That this reasoning is fallacious, and has no foundation in fact, will be very evident on consideration. If this were true, the galleries of crowded churches and theatres would be favoured with the purest air, and the lower parts of rooms would be the foulest; but such is not the case, the very converse holds good. The breath issuing from the lungs on a frosty day does not fall to the ground, but, on the contrary, rises upwards. "It is to a certain extent true, that carbonic acid gas, when highly concentrated, does occupy the lower portion of our atmosphere, as witness the Grotto del Canó, old wells, excavations, brewers' vats, &c; but yet it is equally true, that when mixed with a considerable portion of air, or as emitted from the lungs, it invariably moves upwards. If this were not the case, carbonic acid gas would never be found in the upper portion of inhabited apartments; it is there, however, where it is to be found in largest quantities." The principle of the "diffusion of gases," pointed out by Dalton, is analogous to this idea of the carbonic acid gas remaining at the lower part of dwelling-houses, or forming the lower stratum of air in the atmosphere. We cannot better describe the action of the law of diffusion of gases, by which, in the atmosphere, all noxious and offensive effluvia are diluted, and the uniform purity of the atmosphere kept up, than by quoting the eloquent remarks of a recent reviewer:—

"The carbonic acid, with which our breathing fills the air, to-morrow will be spreading north and south, and striving to make the tour of the world. The date-trees that grow round the fountains of the Nile will drink it in by their leaves, the cedars of Lebanon will take of it to add to their stature, the cocoa-nuts of Tahiti will grow riper upon it, and the plains and bananas of Japan change it into flowers. The oxygen we are breathing was distilled for us some short time ago by the magnolias of the Susquehana, and the great trees that skirt the Orinoko and the Amazon. The giant rhododendrons of the Himalayas contributed the roses and myrtles of Cashmere, the cinnamon trees of Ceylon, and forests older than the flood, buried deep in the heart of Africa, far behind the Mountains of the Moon. The rain which we see descending was thawed for us out of icebergs, which have watched the pole-star for ages; and lotus lilies sucked up from the Nile, and exhaled as vapour, the snows that are lying on the tops of our hills."

We have been thus particular in pointing out the fallacy of the opinion regarding the presumed tendency of carbonic acid gas to assume the lowest position—inasmuch as there is dependent on it the very important question, as to whether the foul air should be withdrawn from our apartments by apertures placed at the lower or upper portion. Its bearing on this important point will afterwards be dilated upon.

In carrying out plans of ventilation, two important points must be remembered—the first is, that no satisfaction in ventilating provisions will be obtained unless apertures or means of ingress for fresh air are provided, in addition to those for the egress of the impure or deteriorated. If the reader will turn to our demonstrations, in connection with figs. 1 and 2, he will there perceive two essential conditions to the proper maintenance of the currents—first, free passage *from* the heated surface of the fire; second, an abundant supply of cold air *to* the heated surface. "Egress apertures alone will be totally inefficient in removing foul air from the interior of any apartment, for air cannot by any possibility be removed, unless there is a corresponding supply of purer and denser air to supply its place; in other words, to supplant it and push it out. The overlooking of this important point is the cause of so many failures in ventilation. The second point to be remembered is, that the apertures for the egress of the foul air should be at the highest part of the apartment. We have already alluded to the opinion held by some, as to the weight of breathed air, causing it to occupy the lower part of the apartment. Hence the recommendation they give for making the egress apertures at the lower part of the apartment for withdrawing foul air. This is the very contrary of the method indicated by Nature herself. We have already pointed out the fallacy of the opinion; but further, it may be as well to consider that it is not "enough to state that the carbonic acid evolved during respiration does not separate from the gases with which it is mingled; the expired air, as a whole, in consequence of its temperature and the moisture associated with it, is specifically lighter, under ordinary circumstances, than the surrounding atmosphere, being composed of carbonic acid gas, azote, and moisture or steam, each being specifically warmer, bulk for bulk and weight for weight, than atmospheric air; and therefore, for a variable period after it is discharged from the lungs, even supposing the carbonic acid gas not to diffuse itself further in the atmosphere, the vitiated air remains above." If, then, the vitiated air be removed by an overhead opening, it will be carried away with the least chance of contaminating the remaining atmosphere. The most rational mode of procedure, therefore, will be to adopt plans in unison with, and dependent upon, the laws of nature; moreover, in accordance with that arrangement which almost universal experience dictates.

RESEARCHES ON THE ESCAPE OF STEAM,

MADE TO DETERMINE THE DIMENSIONS WHICH SHOULD BE GIVEN TO THE ORIFICES OF SAFETY-VALVES OF STEAM-BOILERS.

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THE dimensions of the orifices of the safety-valves of steam-boilers depend upon many circumstances; but chiefly upon the density of the steam, the surface of the boiler exposed to the action of heat, and the management of the fire. But, for the same boiler, under which a good fire is constantly maintained—what is the relation between the density

of the steam and the area of safety-valve, that would make the quantity of steam produced in a given time, equal to the quantity which escapes by the orifice during the same period? For want of positive data, it was "impossible to lay down any precise rule for determining the dimensions of safety-valves; and this point was accordingly left to the judgment of those who construct them."

Under the direction, and with the concurrence of the Government Commission on Steam-engines, I made a set of experiments upon one of the steam-boilers at the manufactory at Chaillot; and the results at which I then arrived formed the basis of a system of instructions subsequently issued by Government, containing the rules to be followed in determining the proper diameters of the orifices of safety-valves.

The boiler placed at my disposal, had two glass tubes, and it presented a heating surface of 5 square metres (square metre = 10·764 square feet.) I attached to this boiler an apparatus which performs the office of a very large stop-cock, but disposed in such a manner as to allow the steam to escape through a rectangular opening made in a thin partition. This opening, which can be increased or diminished at pleasure, was used for the purpose of supplying as many different orifices or openings as were requisite for conducting all the experiments which I made. This apparatus was executed with great accuracy by M. Delenil, and was completely steam tight while the opening was shut.* To measure the elasticity of the steam, I connected the boiler with a large atmospheric manometer, made by M. Collardeau. There was a plunger in the cistern of this instrument, which, with the aid of a screw, could be made to rise or fall, and maintain the surface of the mercury at a constant level, during the time of each observation; one face of the cistern being furnished with a glass disc, upon which was traced the line of level. The tube of the manometer was made of glass, and a scale of copper, exactly divided, and provided with an index, showed the heights of the column of mercury in the tube, in metres and millimetres, which was sufficient for the experiments I had undertaken. A hermetically sealed manometer was also adapted to the boiler, and the indications of this instrument accorded exceedingly well with those of the atmospheric manometer.

During the observations, we noted the height of the barometer, and also of the thermometer, that we might be enabled afterwards to make the necessary corrections. Moreover, no diligence was wanting, and the greatest precautions were taken to give to the experiments every possible degree of precision. I made five series of experiments, nine in each,—giving successively to the opening for the escape of the steam nine different widths. Likewise, I had as many orifices of escape, and the areas of these orifices are expressed in square centimetres by the numbers of the second column of the annexed table. †

Results of Experiments upon the Escape of Steam.

Order of the Experiments.	Areas of the orifices of escape in arithmetical progression (x).	Heights of the column of mercury obtained by the experiments, and tension $t-p$ of the steam in the boiler. 1st Series.	2d Series.	3d Series.	4th Series.	5th Series.	Mean heights of the column of mercury.	Corresponding heights obtained by calculation.	Difference between the mean heights deduced from the experiments and the heights given by calculation.	Products of numbers which correspond in the columns 2 and 8.	Arithmetical progression (y) corresponding to the reciprocal products.
(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)	(9.)	(10.)	(11.)	(12.)
	Square Centimetres.*	Metres.†	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.
1	2·8061	0·434	0·400	0·454	0·428	0·543	0·4518	0·4518	0·0000	1·2678	1·2678
2	2·5510	0·554	0·528	0·570	0·514	0·658	0·5648	0·5417	+ 0·0231	1·4408	1·3817
3	2·2959	0·689	0·629	0·698	0·679	0·794	0·6978	0·6515	+ 0·0463	1·6021	1·4957
4	2·0408	0·804	0·756	0·826	0·774	0·971	0·8262	0·7887	+ 0·0375	1·6861	1·6097
5	1·7857	0·979	0·821	1·022	0·994	1·171	0·9974	0·9652	+ 0·0322	1·7811	1·7236
6	1·5306	1·184	1·111	1·281	1·197	1·425	1·2396	1·2006	+ 0·0390	1·8973	1·8376
7	1·2755	1·404	1·403	1·588	1·506	1·749	1·5300	1·5300	0·0000	1·9515	1·9515
8	1·0204	1·914	1·831	2·021	1·922	2·199	1·9774	2·0242	— 0·0468	2·0177	2·0655
9	0·7653	2·494	2·476	2·610	2·526	2·836	2·5885	2·8478	— 0·2593	1·9810	2·1794
10	0·5102							4·4951			2·2934
11	0·2551							9·4368			2·4073

* Multiply by ·155 in order to obtain square inches. † Multiply by 39·37 in order to obtain inches.

These numbers form an arithmetical progression (x), the ratio of which is 0·2551. The numbers which correspond to these, in the five succeeding columns, express in metres the heights corrected for the pressure of the atmosphere, to which the mercury rises in the tube of the manometer in the open air. These heights, then, of which I have given the mean in the eighth column of the table, measured the elasticities (t) of the steam, diminished by the pressure (p) of the atmosphere. ‡

Before being able to note the results of experiments, it was requisite to make many trials, particularly in those which concerned the feeding of the boiler, and the management of the fire so as to remain in the same condition during the course of the observations. In spite of every precaution which was taken, we see by the table that for the same area of the orifice of escape, the mercury does not rise to the same height in the different series of experiments, and that there are likewise between these heights very sensible differences. It may be remarked that the numbers of the fifth series are greater than those which correspond with them in the first four. This difference depends upon this, that the experiments of the first four series were made with a good ordinary fire, well kept up; in place of which, for the fifth series of experiments, the fire was intentionally strongly urged, so as to give it the greatest activity—so much so as in fact greatly to damage the furnace. These experiments, although made under one exceptionable circumstance, do nevertheless furnish data for the calculation of the mean heights of the column of mercury in the tube of the manometer.

In following the course which I now allude to, I found out a law which connects the results of the experiments as closely as could be wished. I have multiplied the numbers of the second column of the table by their corresponding figures in the eighth, and the products thus obtained are carried into the eleventh column of the table. These products increase as we descend in order from the first, with the exception of the last, which is less than the preceding. This irregularity, and also the want of uniformity which we observe in the increase of the products, depend upon inevitable errors which modified more or less the results of the experiments. It may therefore be inferred, that eliminating these, the products would form the terms of an arithmetical progression.

Admitting this supposition, I observed, after many trials, that to determine the ratio of this progression, the product which it was preferable to take with the first was the seventh; and there resulted for the ratio sought the number 0·11395317. By this number the arithmetical progression (y) is found,

* One of the sides of this opening had a constant length of fifty millimetres; we determined exactly the variable length of the other side by means of a divided arc and a needle, the design of which was furnished to us.

† Metre = 39·37 inches, centimetre = ·3937 inch.

‡ The tension ($t-p$) answers to that pressure which is denominated effective pressure.

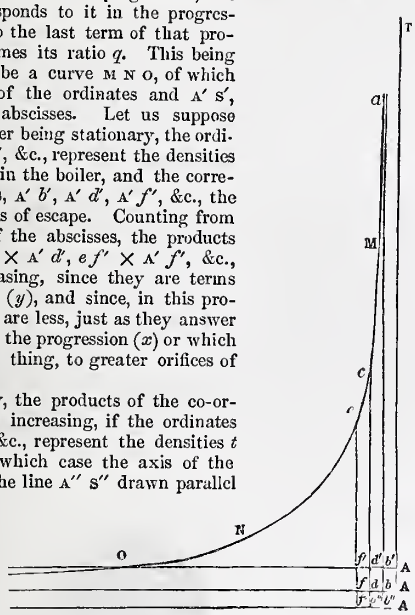
the terms of which are expressed in the last column of the table.

Now if we divide each term of this progression by the number which corresponds to it in the second column of the table, we will have by calculation, the heights of the mercury in the tube of the manometer. These heights are expressed by the numbers of the ninth column of the table. The numbers in the following column, denote the differences between the mean heights, found by experiment, and those given by calculation: and they are so small, comparatively, as to justify my supposition; in fact, allowing for unavoidable errors incidental to experiment, the numbers in the eleventh column would have been in arithmetical progression.

The arithmetical progression (y) just found by calculation, and the terms of which are given in the last column of the table, is an increasing one; the ratio of this progression is $0{\cdot}11395317 = q$. The numbers of the second column are the terms of another arithmetical progression (x) but decreasing, and which has for its ratio $0{\cdot}2551 = v$. In continuing these progressions, we have the tenth and the eleventh terms of each. The eleventh term of the progression (x) is precisely the ratio of that progression.

If in this progression we take any term equal to the last plus n times the ratio v of that progression, the term which corresponds to it in the progression (y) is equal to the last term of that progression less n times its ratio q. This being granted, let there be a curve M N O, of which A′ T is the axis of the ordinates and A′ S′, the axis of the abscisses. Let us suppose that, the manometer being stationary, the ordinates $a\,b'$, $c\,d'$, $e\,f'$, &c., represent the densities $t-p$ of the steam in the boiler, and the corresponding abscisses, A′ b', A′ d', A′ f', &c., the areas of the orifices of escape. Counting from the intersection of the abscisses, the products $a\,b' \times$ A′ b', $c\,d' \times$ A′ d', $e\,f' \times$ A′ f', &c., will go on decreasing, since they are terms of the progression (y), and since, in this progression the terms are less, just as they answer to greater terms of the progression (x) or which comes to the same thing, to greater orifices of escape.

On the contrary, the products of the co-ordinates will go on increasing, if the ordinates $a\,b''$, $c\,d''$, $e\,f''$, &c., represent the densities t of the steam, in which case the axis of the abscisses will be the line A″ S″ drawn parallel to A′ S′ through the point A″ distant from the point A′ by a quantity which would represent the pressure p of the atmosphere equal to 0·76 metres. But it is a matter of indifference whether the axis of the abscisses are made to pass through the point A′, or through the point A″.



Let us suppose this axis always to pass through the first of these points, and let us suppose that the surface of the orifice of escape is represented by the absciss A′ b' equal to the eleventh term of the progression (x) or which is the same thing to the ratio v of that progression. Making the correspondent ordinate $a\,b' = h$, we shall have the product $h \times v$. Let there be any other absciss A′ $d' = s$, and its ordinate $c\,d' = r$, we shall have the second product $r \times s$. After what has been said above, the second product ought to be smaller than the first, and the difference between the two will be equal to $\frac{q}{v}(s - v)$. We will then have the equation

$$h \times v - r \times s = \frac{q}{v}(s - v);$$

from which we shall get by substituting for r its value $t - p$

$$t = p - \frac{q}{v} + \frac{h \times v + q}{s}$$

This equation, which may be put in this form,

$$t = a + \frac{b}{s} \quad . \qquad (\text{A})$$

by making the constant quantities $p - \frac{q}{v} = a$ and $h \times v + q = b$.

belongs to the hyperbola. To prove this, let us draw A S parallel to the line A″ S″; and at a distance from this last A″ A $= p - \frac{q}{v} = a$. This line A S will be one of the asymptotes of the hyperbola. So that if $s = \infty$, $t = a$, and the curve will meet the line A S, at an infinite distance. If we make $s = 0$, we have $t = \infty$, and the curve shall meet A T at an infinite distance. This line then is the other asymptote of the hyperbola.

Now let $t - a = t'$, in which case the intersection of the co-ordinates of the curve will be A, and the equation will become $t' \times s = b$. Also, the products of the co-ordinates are equal to a constant quantity b. Now this equality of products is the characteristic property of the hyperbola.

The equation (A) shows that the density or elasticity t of the steam in the boiler, is equal to a constant quantity a, plus a variable quantity $\frac{b}{s}$ which depends upon the surface s of the orifice of escape.

From this equation we find $s = \dfrac{b}{t - a}$ . . . . . (B)

The surface s increases, in proportion as t diminishes; but it becomes infinite, only when $t = a$. The pressure of the atmosphere, or $p = 0^{m}.76$. (29·92 inches). We have seen above that $q = 0{\cdot}11395317$, and $v = 0^{cm}\ {\cdot}2551$, ($\frac{1}{25}$th of an inch nearly). In dividing the 11th term of the progression (y) by the corresponding term of the progression (x), we find $h = 9{\cdot}4368$. With these numerical values, we shall have

$$a = p - \frac{q}{v} = 0{\cdot}3133$$

$$\text{and } b = h \times v + q = 2{\cdot}52128085$$

Substituting these numbers for the constant quantities, a and b, in the equations (A) and (B), these equations will give *directly*, first, t, expressed in atmospheres of $0^{m}.76$, when we shall thence find s; and secondly, s, expressed in square centi-metres; and thence we find t, for a heating surface of five square metres ($5\frac{1}{2}$ square yards.)

If instead of taking the mean of all the experiments, we should take those only of the fifth series which were made with a fire urged as strongly as possible, we shall have $q = 0.10287818$; $h = 10{\cdot}00585692$, and find $a = 0{\cdot}35671431$, and $b = 2{\cdot}65537228$. Thus the numerical values of the quantities a and b, constant for the same state of the fire, augment in proportion as the fire becomes more active, and, by necessary consequence, with equal elasticity, the area s of the orifice of escape augments also. It is evident that, in this case, the line A S removes from the line A″ S″.

Let a', b', s', represent the quantities which relate to the experiments of the fifth series taken alone. We shall have for the numerical value of s', in making $a = 0{\cdot}35671431$, and $b = 2{\cdot}65537228$, the equation

$$s = \frac{b'}{t - a'}$$

If we divide this equation by the equation (B) we shall have

$$\frac{s'}{s} = \frac{b'}{b} \times \left(\frac{t - a}{t - a'}\right)$$

This equation, which shows that the quotient $\frac{s}{s'}$ becomes less, as t is greater, gives us the values in the following table :—

Elasticity of steam in Atmospheres.	Values of $\frac{s'}{s}$
0·469361	∞ . . . .
0·5	3·016773 . . .
1·	1·114330 . . .
1·5	1·112962 . . .
2·	1·092489 . . .
2·5	1·082811 . . .
5·	1 066463 . . .
10	1.059500 . . .
20	1.056264 . . .
∞	1053184 . . .

The increase of the area of the orifice of escape, though greater for the less elasticities, is nevertheless very small, even for a

pressure of $1\frac{1}{2}$ atmospheres, in which case $s' = 1{\cdot}112962 \times s$. Therefore, if, in this instance, s be doubled, the area of the orifice is greater by $0{\cdot}887038 \times s$, than what is requisite for the escape of steam raised under the action of a very strong fire.

The experiments which I made upon the escape of steam, and the conclusions which I have drawn from them, furnish the means of determining the area of an orifice in a steam boiler such, that the quantity of steam which shall escape from that orifice, in a given time, shall be equal to what is produced in the same time, in which case, the elasticity of the steam in the boiler will remain constant, and the manometer stationary.

The area of orifice necessary to certify this condition is calculated by the equation,

$$s = \frac{2{\cdot}52128085}{t - 0{\cdot}3133},$$

which is the equation (B), with the quantities a and b, stated numerically.

I have said that this equation gives s for a heating surface of 5 square metres. But, other things being equal, the value of s varies as the quantity of steam formed, and it is admitted, that with a constant elasticity, the steam formed is in proportion to the heating surface; consequently the value of s is also proportional to that surface. It follows therefore, that we have for the unit of the heating surface,

$$s = \frac{0{\cdot}50425617}{t - 0{\cdot}3133},$$

and for c square metres of heating surface,

$$s = \frac{0{\cdot}50425617 \times c}{t - 0{\cdot}3133} \quad - \; - \; - \quad (c)$$

This equation gives, in general, the area of orifices of escape, whatever be their figure. If, as is usual with safety-valves, the orifices be circular, they will have, other things being equal, the same areas, their diameters being formed by the following formula:—

$$d = 0{\cdot}918066 \sqrt{\frac{c}{n - 0{\cdot}41223684}}$$

which gives the diameters d, in centimetres. In the calculation leading to this formula, we have made

$$t = n \times p. = n \times 0{\cdot}76 \text{ metre},$$

n being in atmospheres the tension of the vapour in the boiler.

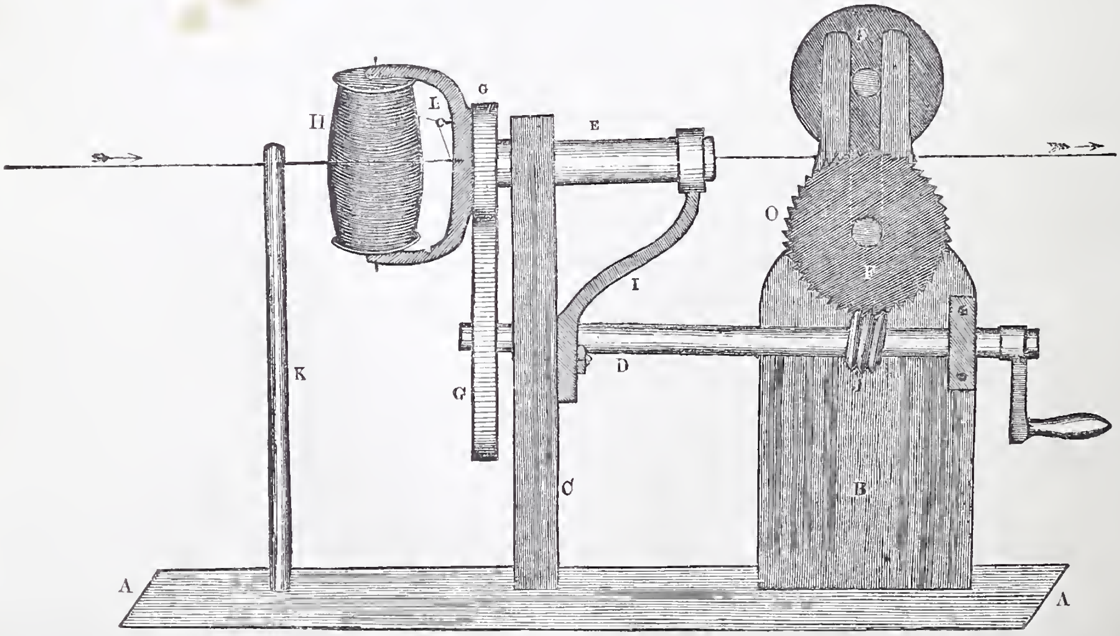
In determining with this formula, the diameters which ought to be given to the orifices of safety-valves, these valves would suffice for an ordinary development of steam, if at all times they opened entirely, and opposed no obstruction to the escape of the steam. However, to regulate the diameters of valves of this kind, in the ministerial regulations on the subject lately issued, the coefficient of the formula is 1·299837, giving double the area of orifice obtained, with the coefficient 0·918066 resulting from my experiments.

It has been thought that, though safety-valves be made according to the rules I have deduced, it would nevertheless be convenient, for the purpose of greater security, to increase their orifices. But it should be observed, that after what has been said above, it would be unnecessary, even for the escape of steam generated by the most active furnace, to double the areas of the orifices; and that a very little enlargement would be sufficient.

According to the same regulations, the valves in common use must be double the diameters of orifices of such as opened entirely; because, first, these valves could be raised only by an excess of steam in the boiler; and, secondly, the orifices of the valves, being always partly obstructed, do not afford an entirely clear passage to the steam issuing from the boiler.

If these valves opened entirely, they would have, with diameters found as above, orifices much too large, since the areas of these orifices would be eight times the area s, found by the equation (c). But, as I have just said, these valves are simply raised, whence it follows, that the steam escapes only by an opening of which the cylindrical surface is equal to the product of the circumference of the orifice, by the height through which it rises. The surface, then, of the opening, cannot equal that of the orifice of the valve, till that height becomes equal to one-fourth of the diameter of that orifice. But this case would be quite an exception, as the valves do not rise nearly so high in general. They open gradually to the point sufficient for the escape of the steam, unless there happens any commotion in the interior of the boiler, from the sudden escape of the steam.

WIRE-COVERING MACHINE.



A A, sole of machine, made of wood, into which are mortised the two uprights, B B, only one of which is shown—they are placed about three inches apart. C, upright frame for carrying shaft, D, and tube, E. F F, two rollers for drawing through the wire as it is covered; the top roller is made of lead, so as to give pressure to the wire to take it through. E, tube or hollow spindle

through which the wire passes. G O, spur wheel and pinion for driving hollow spindle and bobbin H. I, bracket for carrying end of hollow spindle. J, endless screw for working the pulley wheel O, fixed on the outer end of the under roller F. K, support for steadying the wire as it passes through the spindle E. H, bobbin containing the thread for covering the wire. L is a small eye fixed into the frame that carries the bobbin, through which the thread passes on to the wire. In using the machine, wire to be covered is held by the hands, and kept stretched as it is drawn through by the two rollers; another pair of rollers might be applied to keep the wire stretched, the same as the drawing rollers.

The speeds of the machine are as follow—viz., large wheel, 60 teeth; pinion, 15 teeth; drawing screw, 6 teeth to the inch; pulley for do., 35 inches diameter; drawing rollers, 3 inches diameter.

PRACTICAL BLUNDERS.

It is not many years since the discovery of the perpetual motion was a subject of grave discussion, and numerous individuals of high ingenuity wasted their time, and exhausted their means, in futile contrivances intended to realize a notion which nobody had shown to be impossible. A more general diffusion of sound knowledge has of late thrown popular discredit on pursuits of this chimerical nature, and replaced the delusions which occupied minds of an inventive turn, by projects of a more rational character. Still, however, the subject is now and again revived by some young mechanical novices, who, for a short period of their noviciate, imagine themselves endowed with a higher degree of inventive genius than ever before fell to the lot of any single contriver. A young man, in the first year of his apprenticeship, struck with the beauty of the machinery which he sees around him, and as yet but ill-acquainted with the principles of its construction, and having heard a deal about a perpetual motion, begins to plan, and lights upon a project which he feels sure could not have been before thought of, and it must succeed. Many a sleepless hour it costs him, and it is only after a salutary exhibition of the absurdity of his scheme to astonish the world by his powers of invention, that he is cured of his self-idolatry.

It may not be difficult to see why the particular contrivance failed in producing the expected effect; but it is not therefore manifest that all contrivances would similarly fail, or, that the problem is practically impossible; and, supposing the novice after his failure were to inquire at some of his more experienced acquaintances—some one perhaps whom he has heard ridiculing the notion in the strongest terms as grossly absurd—would he receive a convincing statement of the insurmountable difficulty? Put the question broadly—why is a perpetual motion, in the sense in which mechanics understand it, impossible? It is not enough to say, that great and numerous attempts have been made to attain it, and all without success; for the question just recurs —why did they fail? If they failed for want of ingenuity, then a perpetual motion is possible; but that is denied—then wherein consists the cause of failure?

It is in this way that we may suppose the experienced derider of perpetual motions to be "pushed home" by his young experimenting friend, and he will require some knowledge of mechanical principles to escape without humiliation. The attempt is not always successful: we have been witness to more than one case in which the strength of the argument lay on the wrong side. We have even met with instances, where, at the same time that the notion of a perpetual motion was ridiculed in unqualified terms, exactly the same absurdity was admitted indirectly, as one of the most easy and practicable things which could be imagined. As a palpable case, we have heard a gentleman of veracity state, and maintain the statement, that he had observed in the course of his travels, which were not very extensive, an apparatus, consisting of an overshot wheel and pump, for clearing a quarry of bed-water; and that the wheel was driven by a portion of the same water which the pump lifted. Now this is the very beau ideal of a perpetual motion. Here was a pump capable of lifting more water than was required to work it—consequently, the superfluous water being so much extra power, might have been applied to do other work—as lifting stones and the like. And farther, the same apparatus might be erected over a tank of water, and it would work on so long as the machinery remained in good repair—and the power which it furnished after driving itself might be applied to any useful purpose. But what are the real facts of the case? Supposing the machinery once fairly set in motion, and supposing that its motion was retarded by no friction or other resisting cause, and that there was no waste of water by leakage, then would it continue to work for an indefinite time—the pump would go on, lifting the water to the height from which it descended upon the wheel, but not the millionth part of an inch higher.

In fact, as the pump obviously can give no power, the whole apparatus might be viewed as a single water-wheel, in which the ascending side received at the bottom, and carried up with it just as much water as the descending side received at the top to carry down; and in such an arrangement, it is manifestly of no consequence, whether the water ever leaves the wheel or not; that is, whether it be thrown off by the descending buckets at the bottom, and taken in by the ascending buckets at the same point, or be simply carried round with the revolutions of the wheel without displacement from the buckets into which it was first poured. And if this be true, it is not very difficult to see that the wheel would move *ad infinitum*, just as well without the water at all! Now, the real circumstances are these: The effective power of the best constructed overshot water-wheel, is only 70 per cent. of the power which drives it; that is, for every 100 gallons of water expended upon driving it, it would lift 70 gallons to the same height, and no more; and a pumping apparatus must be very well constructed indeed, to give an actual result equal to 70 per cent of the power of the wheel. Here, then, there is a loss of 30 per cent. of power in working the apparatus, and consequently, all the water lifted by the pump would just be half sufficient to keep up the motion, without requiring the machinery to do any other work.—So much then for not knowing how to observe.

The case which we have here noticed is palpably absurd to every mechanic who knows anything about hydraulic machines; but the same absurdity has sometimes been scarcely less glaringly introduced into the schemes of ignorant projectors. Many of these worthies, in the plenitude of their presumption, undertake to create power by complex combinations of mechanical elements which they obviously do not understand. Within perhaps 200 yards of where we write, still stands, for aught we know to the contrary, a specimen of this sort on which we believe not less than £1000 were spent, and which was not patented only in consequence of the death of the projector. The money belonged to a person, who fortunately, can sustain the loss of it without serious inconvenience, and who perhaps deserved to pay the penalty of his ignorance; the merit of the contrivance belonged to one of those individuals who would rather scheme than work, and who had just that amoumt of mechanical knowledge which is dangerous. The machine alluded to is likewise a hydraulic one, and its pretended object was to save $\frac{3}{4}$ths of the water used, by pumping it up again to the top of the fall, and this without loss of effective power in the machine!—This person, and his employer, no doubt laughed loudly together at the absurdity of a perpetual motion.

But all the great projectors of this class are not simply water-doctors. We have known them take to contrivances for "lifting great weights without loss of speed," and find their multiplicity of pulleys, wheels, and pinions, bent and straight levers, all resolvable into a value, little superior to that of a single pulley. This is fact; we have seen such a combination of mechanical elements, and for such an object, on which a man—a great genius in his own and his employer's estimation—worked for upwards of two years with bolted doors, and every other precaution against the mighty secret being divulged to the wondering world. —We never hear of such precautions without thinking of the fable about a mountain in labour bringing forth a mouse.

These are a sample of practical blunders, resulting from an ignorance of the first mechanical principles; but there are others which have been committed, hardly less palpable for the ignorance displayed of the first principles of experimental philosophy. There is a case related somewhere of certain sapient parties, who proposed to blow their furnace fires with bellows having a nozzle two miles in length, and were astonished when they did not succeed. The case was this—at the distance of two miles from a blast furnace, was an unemployed waterfall; this suggested the idea that by erecting great bellows at the fall, to be

driven by a water wheel, a vast saving would be effected. The pipe was laid and the other necessary apparatus was erected, but it was discovered when all was in order, and the water-wheel was set in motion, that no blast arrived at the furnace. As nobody concerned had any doubts about the practicability of the project, it was sagely concluded that the pipe must be stopped. To find out whether this was positively the case, a cat was put in at one end of the pipe, and madam grimalkin walked very gravely out at the other end. Every one of course was amazed that a cat could find a passage where a blast of air had stuck. A week's study of pneumatics would have saved the expense and trouble of the proprietor, and the anxiety and humiliation of the projector, not to speak of the needless expedition of the philosophical cat.

A very apt case of ignorance of principles as to blowing a furnace effectually, is related by Sir J. Herschel. As every body knows, the smelting of iron requires a violent heat, and this is usually raised by great iron bellows, driven by a steam-engine. But, instead of employing this power to force *air* into the furnace through the intervention of bellows, a great projector (in his own opinion), argued that, as steam is composed of the two gases, oxygen and hydrogen, the first of which is the essential part of the air which supports combustion, and the other, the most inflammable body known; the introduction of a violent blast of highly elastic steam from the boiler at once into the furnace, would have the effect of increasing the fire to a ten-fold fury. This seems to have been unanswerable reasoning to all concerned, and accordingly apparatus adapted to this new form of blast was prepared. It had not the effect, however, of increasing the intensity of the fire to the degree expected—*it blew it out;* a result, as Sir John remarks, which a slight consideration of the laws of chemical combination, and the state in which the ingredient elements exist in steam, would have enabled any one to predict without a trial.

It was perhaps this sage experiment, which of late suggested the notion of extinguishing fires by means of steam, instead of water. Most speculative folks run into extremes, and when it was discovered that steam would extinguish fire, it was at once concluded that it must be the best thing for effecting that object. But experiments have been made on the subject, and we like conclusions best which rest on experiment. Let us take a specimen:—A cage-grate full of live coals was lowered into the cabin of a steam-boat; all the windows, doors, and hatches, were then closed, and steam, by means of a pipe from the boiler was thrown in; and to the great satisfaction of all beholders, the fire was extinguished! We wonder if none of the parties made any calculation of the time which the fire, under these circumstances, would have burned, had no steam been introduced. The subject no doubt did well enough to make a paper upon for the British Association; but we suspect it would hardly have answered so well before an association of firemen: these people know very well that there is sufficient heat in a flaming building to convert the water they throw upon it into steam, without being at the trouble of boiling it into steam beforehand.

The gifted author whom we have already named, has preserved the remembrance of a practical blunder of a more melancholy nature, but one which is highly instructive. "After the invention of the diving-bell, and its success in subaqueous processes, it was considered highly desirable to devise some means of remaining for any length of time under water, and rising at pleasure without assistance, so as either to examine, at leisure, the bottom, or perform, at ease, any work that might be required. Some years ago, an ingenious individual proposed a project by which this end was to be accomplished. It consisted in sinking the hull of a ship made quite water-tight, with the decks and sides strongly supported by shores, and the only entry secured by a stout trap-door, in such a manner, that by disengaging, from within, the weights employed to sink it, it might rise of itself to the surface. To render the trial more satisfactory, and the result more striking, the projector himself made the first essay. It was agreed that he should sink in twenty fathoms water, and rise again without assistance at the expiration of twenty-four hours. Accordingly, making all secure, fastening down his trap-door, and provided with all necessaries, as well as with the means of making signals to indicate his situation, this unhappy victim of his own ingenuity entered and was sunk. No signal was made, and the time appointed elapsed. An immense concourse of people had assembled to witness his rising, but in vain; for the vessel was never seen more. The pressure of the water at so great a depth had, no doubt, been completely under-estimated, and the sides of the vessel being at once crushed in, the unfortunate projector perished before he could even make the signal concerted to indicate his distress."

Speaking of the diving-bell recalls a project of an opposite character. The object of this was no less than safe and easy transport to any part of the world, at a moment's notice—travelling in fact unattended by any of the risks and inconveniences of sea-voyages and railway stages. The method, as set forth by the ingenious projector, consisted in getting elevated in a balloon beyond the reach of the earth's attraction, and there to remain stationary, till the earth by its motion on its axis, brought that part of its surface which the aëronaut wished to reach, immediately under the balloon, which was then to descend. In this way a voyage from England to America, was to be reduced to a comfortable seat in a balloon-car for a few hours, during which the aëronaut might amuse himself in making a map of the portion of the earth's surface passing beneath him. The boldness and ingenuity of this scheme goes so far beyond our notions of a practical blunder, that we seriously recommend the project and the projector to the consideration of the British Balloon Company, the directors of which are, no doubt, well qualified to appreciate both.

Ignorance of the first principles of geology have led of very late years to the most ruinous consequences. How many disastrous mining adventures would have been prevented, had the parties but taken the trouble to learn, from competent authority, the order of strata which compose the earth's crust, and the nature of the rocks among which the mineral sought was known to be found! An instance, within our own personal knowledge, occurred within about 20 miles to the north of where we write. The surface of the country is composed of that bed of rocks, called by geologists the old red sandstone, which every one in the least degree acquainted with the subject knows to lie immediately *beneath* the coal-beds. Yet, in the face of this fact, several attempts have been made, at great expense, to establish collieries in the locality. The history of mining operations, to be sure, is full of similar cases; and it is therefore less to be wondered that a few fox-hunting squires, with a duke at their head, should be caught in a folly.

Ignorance of mechanical principles is even felt in the medical profession, where perhaps few would expect that they had any place. Dr Arnott, an excellent judge in these matters, has the following remarks, which are too correct:—

"Some surgeons," says he, "possessing a certain degree of knowledge in mechanics, but only that degree which is dangerous, having heard that the lever was a powerful engine, have tried to replace bones solely by leverage, as they call it. Thus, a man's dislocated arm has been placed over the back of a chair as a fulcrum, or over the top of a door; and while the weight of the suffering body was hanging to it on one side as the resistance, force has been applied to the other side—enough sometimes to break the bones, or to tear away the ligaments and soft parts about the joint. Other surgeons, after hearing in the same way the effects of the pulley, have wished to do all by irresistible extension, and instead of borrowing the moderate assistance which might be useful, have torn muscles and ligaments from their attachments."

Pope must surely have known something of such horrid treatment, when he wrote his much criticised line,

"A little knowledge is a dangerous thing."

The tortures inflicted on patients, by imaginary cures for incurable diseases, are still too common, but will undoubtedly become less frequent, as the principles of physiology become better and more widely known.

METHODS OF ANALYZING CLAY IRON ORE.

WITH PROFESSOR FUCH'S PROCESS.

This ore occurs in strata, called by the workmen beds or bands, varying from two to fourteen inches in thickness, alternating with beds of clay, coal, bituminous schiste (shale), and sometimes limestone. The most of the iron manufactured in this country is from this ore. The average proportion of iron procured from clay ironstone is thirty per cent.; the other ingredients are principally clay, lime, and coaly matter; its colour varies, according to the proportion of the latter, from light-brown to black. The following details for the analysis of clay iron-

stone, may be interesting to the readers of the Journal, as well as useful to those concerned in the manufacture of iron—it being of the utmost importance to know the richness of the ore in metal, and the proportion of the other materials, so as to regulate the quantity of fluxes in the fusing or BLAST FURNACE. When an unknown substance is put into the hands of a chemist for the purpose of analysis, his first object is to determine the number and character of the ingredients which compose the substance, and accordingly, he arranges the best plans of separating these ingredients, so as to determine their proportion, either by weight or measure; but for a substance such as clay iron ore, the constituents of which are well known, the former of these operations is unnecessary. The principal constituents of clay iron ore, are, protoxide of iron, carbonic acid, silica, alumina, lime, magnesia, bituminous matter, with sometimes a little oxide of manganese and sulphur—the last two when they do occur, are in very minute proportions.

1st. The sample to be analyzed is to be bruised with a hammer—a steel mortar, if convenient, suits best—to a coarse powder. It is then ground in a mortar—one made of agate is best—till it is so fine that no grittiness is felt between the fingers, after which it is submitted to a heat not exceeding that of boiling water, for a few minutes, to expel any moisture that may have been absorbed, or accidentally combined with the mineral. While this is going on, mix together in a bottle, two ounces muriatic acid, with half an ounce nitric acid, both pure; then weigh twenty-five grains of the dried powder, and put into a clean flask with one half of the nitro-muriatic acid; boil over a spirit lamp or on a sand bath for fifteen minutes; then allow the insoluble matter to subside; pour off the clear solution into a jar, and add the rest of the acid to the flask, and boil again for other fifteen minutes. When this has settled, decant the clear solution into the jar, and add a little distilled water to the insoluble matter in the flask; this is filtered through a weighed piece of bibulous paper, and the insoluble matter washed upon the filter, until the water passing through gives no indication of acid; this is known by catching a drop or two in a small glass, and adding a little nitrate of silver, a white precipitate is given so long as acid is present. The insoluble matter is silica and coal, which, with the filter, is thoroughly dried and weighed, deducting the weight of the filter. The powder is put into a small open crucible, and kept at a red heat over a spirit lamp for fifteen or twenty minutes; this burns off the coal. When cool, it is again weighed—the loss indicates the amount of coal; what remains is silica, which is noted.

2d. The whole water which passed through the filter is put into a basin, and evaporated down to a small quantity, and then added to the clear solution in the glass jar, to which liquid ammonia is added so long as a precipitate is thrown down; this is again filtered through a weighed filter, and washed, to save repetition; in all cases the precipitates are washed until nothing but pure water passes through the filter, which washings are carefully kept, and to prevent accumulation, evaporated as above; this precipitate is peroxide of iron and alumina. It is dried and weighed; after which it is dissolved in a little muriatic acid, and then caustic potash is added in excess—the iron is again precipitated, and the alumina is dissolved; this is again filtered, washed, dried, and weighed; the loss indicates the alumina; what remains is peroxide of iron. Should the operator wish to obtain the alumina, it may be precipitated again from the potash solution by muriate of ammonia (sal-ammoniac).

3d. To the filtered solution of No. 2, a solution of oxalate of ammonia is added, as long as a precipitate is formed; this is again filtered through a weighed filter, washed, and dried at a temperature not exceeding 212° Fah., and then weighed. This precipitate is oxalate of lime.

4th. To the filtered solution of No. 3, a solution of phosphate of soda, and an equal quantity of liquid ammonia are added; if magnesia be present, a white precipitate is the result; this is again filtered, the precipitate washed, dried, and weighed. This is the double phosphate of magnesia and ammonia.

We have thus separated the principal ingredients which enter into the composition of clay iron ore—the other matters are only occasional constituents, and are immaterial in a practical point of view. Were a strict analysis required, other processes would be necessary; but to detail all these, in a paper of this kind, is neither interesting nor necessary.

The next object of the operator is to draw up a report of the quality of his mineral. The precipitate of No. 2, which is the peroxide of iron, is first taken; the iron existed in the mineral as the carbonate of the protoxide; but when dissolved in the acids, the carbonic acid is given off, and the iron combines with the acids, and also with another proportion of oxygen—these acids being again neutralized by the ammonia, the iron precipitates as a peroxide. Now, suppose that the weight of the peroxide obtained is twelve grains, how much pure iron is there? This is calculated from the atomic weights of the substances; the atomic weight of iron is 27·18, that of oxygen 8; these are combined in the peroxide in the proportions of 2 iron and 3 oxygen = 78. The following will be the calculation, omitting the fractions:—

$$78 : 54 :: 12 : x = 8{\cdot}3.$$

The result, 8·3, is the amount of pure iron in 25 grains, which multiplied by 4, gives 33·2 as the per centage.

The precipitate of No. 3 is the oxalate of lime, which lime also existed in the mineral as a carbonate. According to the atomic weight of this precipitate, every 73·74 grains of the precipitate is equivalent to 50·62 grains of carbonate of lime existing in the mineral. Suppose the weight of the precipitate be 7 grains; then as $73{\cdot}74 : 50{\cdot}62 :: 7 : x$; the result will be the quantity of carbonate of lime in the mineral.

The precipitate of No. 4 is the phosphate of magnesia and ammonia; every 237·1 grains of this precipitate is equal to 85·4 grains of carbonate of magnesia in the mineral; the result is reduced in the same manner, if the weight of the precipitate be 5 grains; as $237{\cdot}1 : 85{\cdot}4 :: 5 : x =$ the amount of carbonate of magnesia in the mineral. These are the ingredients, the proportions of which it is necessary for the practical man to know. Any of the others may be calculated in the same manner, by adding together the atomic weight of their elements, and calculating as above.

It must be admitted that the analysis of clay ironstone is one of as tedious a nature as any which comes under the attention of the chemist, branching as we have seen, when properly conducted, into two separate and distinct analysis, viz., that of the portion soluble in an acid, and consisting principally of that portion of the ore which existed as carbonate, the other portion insoluble, and consisting of carbonaceous matter and silicates. For this reason, the method described above is seldom adopted by ironmasters, or others who have daily to examine samples of ore for the purpose of ascertaining their value; they generally having recourse to an assay by the dry way, which is usually conducted in a very slovenly manner. This mode gives only a very rude approximation of the quantity of iron existing in a sample, without indicating the nature of the impurities: these, being pretty constantly of the same nature in the clay iron ores of any district, are, in the generality of cases, overlooked; although, as the fluxes should be varied with the quality of the ore, this ought not to be the case.

A very neat method of ascertaining the quantity of iron existing in an ore, was pointed out some time ago by Professor Fuchs. It is founded on the fact, that muriatic acid is incapable of dissolving metallic copper, provided the air be excluded but if a piece of copper be put into a solution of a persalt of iron in muriatic acid, the persalt is converted into a protosalt, and a quantity of copper is dissolved, forming a protosalt of copper, exactly equivalent to the quantity of peroxide of iron contained in the solution.

Into a solution of peroxide of iron in muriatic acid, put a piece of copper, the weight of which is accurately known; boil it well, until no more copper is dissolved; weigh the undissolved copper after having cleaned and dried it; and thus ascertain how much copper has been dissolved. The quantity of peroxide of iron contained in the solution, is to that of the copper dissolved as their respective equivalents, viz., as 5 to 4 (accurately 40 to 31·7). Therefore, if 4 copper be dissolved, it indicates 5 as the quantity of peroxide of iron originally contained in solution.

For the purpose of ascertaining the quantity of iron contained

in an ore according to this method, proceed as follows:—Having reduced a portion—say 50 grs.—of the ore to fragments the size of a peppercorn, digest in a flask by a gentle heat, with rather more than a fluid oz. of muriatic acid, until solution takes place; then, in order to peroxidize the iron, add cautiously, by small portions at a time, 20 grains of chlorate of potash—nitric acid is inadmissible; continue the digestion for a short time; then boil and add a slip of clean copper previously weighed, and which, as a precautionary measure, should equal in weight the quantity of ore operated on; continue the boiling for ten minutes; then remove the flask as speedily as possible, and fill it up with hot water; pour off, and remove the copper; clean, dry, and weigh it—the loss, as already stated, will indicate the quantity of iron existing in the ore under examination.

As an example, the writer dissolved 50 grs. of clay ironstone in the foregoing manner, and boiled with it a slip of copper weighing 53·85 grs.; after being boiled, washed, and dried, it was found to weigh 36·8 grains,—17·05 grains had therefore been dissolved. Now every 4 grains of copper so dissolved, indicates 5 grains of peroxide; therefore, 4 : 5 : : 17·5 : 21·31 = 14·91 iron, or 29·82 per cent.

Since the writer became acquainted with this process, he has followed it in preference to any other, as he finds it expeditious and susceptible of extreme accuracy. He conceives, therefore, it may not be unacceptable to the reader to add a few instructions and examples from the paper of Professor Fuchs on this subject:—

The following precautions must be observed in order to obtain accurate results. The copper must be in a state of purity. The hydrochloric acid must be also pure, tolerably concentrated, and employed in excess. Nitric acid should not be used for bringing the iron to the state of peroxide, but either a stream of chlorine, or, what is preferable, chlorate of potash. Upon adding the piece of copper to the solution, it must immediately be brought to the boiling point, and kept there in order to prevent access of air. Previously to removing the undissolved copper from the solution, hot water is to be added till the vessel is quite full; this is to be poured off, and fresh hot water to be added: the copper, which is generally covered with a brownish coating, is then carefully washed in cold water, dried at a gentle heat, and then weighed. The foregoing process has this advantage, that the substances ordinarily met with in iron ores—such as silica, alumina, magnesia, lime, oxide of titanium, oxides of manganese, the phosphoric and sulphuric acids, &c.—do not in any way interfere with the accuracy of the results. An iron ore containing arsenic, however, cannot be analyzed on this principle, as blackish gray scales of arseniuret of copper are deposited on the metallic copper.

This process is applicable to the examination of cast-iron, or iron of other kinds, and also for the comparison of one sort of iron with another.

Among many experiments which were made, M. Fuchs relates the following:—

Exp. 1.—50 grains of very soft English iron were dissolved in hydrochloric acid, and brought to the state of peroxide by chlorate of potash; 85·8 grains of pure copper were boiled in this solution, of which 56·2 grains were dissolved. Therefore, as 31·7 : 28 : : 56·2 : 49·46, which is equal to 98·92 per cent. of pure iron. A repetition of this experiment gave 99·19 per cent.

Exp. 2.—50 grains of piano-forte wires were examined, which indicated 98·75 per cent. of pure iron. The iron in this experiment was peroxidized by a current of chlorine; a considerable deposit of carbon was formed during the process of solution in hydrochloric acid, which, however, disappeared upon passing chlorine through the solution.

Exp. 3.—50 grains of gray and white cast-iron from Bergen were examined, and gave 94·33 per cent. of pure iron: the impurities, on examination, were found to consist of

Carbon,	3·43
Silica,	1·75
Phosphorus,	0·37
Sulphur,	0·12
	5·67

Exp. 4.—70 grains of crystallized carbonate of iron from Lobenstein, examined, gave equal to 56·9 per cent. of protoxide equivalent to 91·68 per cent. of carbonate of the protoxide; the other constituents consisted of carbonate of the protoxide of manganese, and carbonate of lime and magnesia.

Exp. 5.—70 grains of specular iron ore from Gleissing, in the Fichtelgebirge, gave, upon examination, a quantity equal to 92·30 per cent. of peroxide of iron, and 7·40 per cent. of silica, leaving only a loss of 0·3 per cent.

Exp. 6.—Crystallized magnetic iron, containing both protoxide and peroxide, was next examined. 50 grains were dissolved in hydrochloric acid, to which chlorate of potash was added, to bring the whole of the iron to a state of peroxide. 40·71 grains of copper were dissolved, which is equivalent to 51·36 of peroxide of iron, or 102·72 per cent. Another portion of 50 grains was dissolved, without the addition of chlorate of potash; the copper taken up was only 27·1 grains, equivalent to 34·2 grains of peroxide of iron, or 68·4 per cent.; this deducted from 102·72, indicated by the first 50 grains, gives 34·32, corresponding to 30·88 protoxide of iron: consequently, this mineral gave

Peroxide of iron,	68·40
Protoxide of iron,	30·88
Loss,	0·72
	100·00

This process is applicable, in many instances, to the determination of the quantity of copper contained in ores of that metal.

The ore of copper is to be dissolved in hydrochloric acid, care being taken that the whole of the copper is converted into oxide or chloride; the solution is then to be boiled with copper (the necessary precautions having been first duly observed), until it assumes a pale olive-green tint, and becomes colourless on being diluted with water. If no oxide of iron be present, precisely the same quantity of copper will be transferred to the solution as was originally contained therein; the quantity of copper remaining is to be subtracted from the quantity of reguline copper employed in the experiment, in order to ascertain the amount of copper contained in the copper ore examined. 100 grains of pure malachite were examined in this manner, and gave equal to 57·5 of pure copper, which is very nearly the quantity that should be obtained; had the quantity of copper dissolved proved considerably less, it would have shown that the malachite was not in a state of purity.

ORDERS OF ARCHITECTURE.

CHAPTER II.

OF THE GRECIAN DORIC ORDER.

This order, illustrated by Plate II., is the most ancient of the orders, and, while employed by the Greeks, was without a base. The surface of the shaft is usually worked into twenty very flat flutes, meeting each other at an edge—this will be explained by the half plan given in the plate. The edge is sometimes a little rounded—the upper member of the capital is a square abacus or thin plinth, under which there is a large and elegant ovolo of great projection; on the base or lower part of the ovolo, there are three fillets or annulets, which project from the surface of the ovolo, and have, of course, equally recessed spaces betwixt them; the flutings of the column terminate on the under sides of the lowest of these fillets, being finished by a cavetto or a conge. The general outline formed by the junction of the conge with the ovolo, constitutes a cyma-reversa, the effect of which is most graceful.

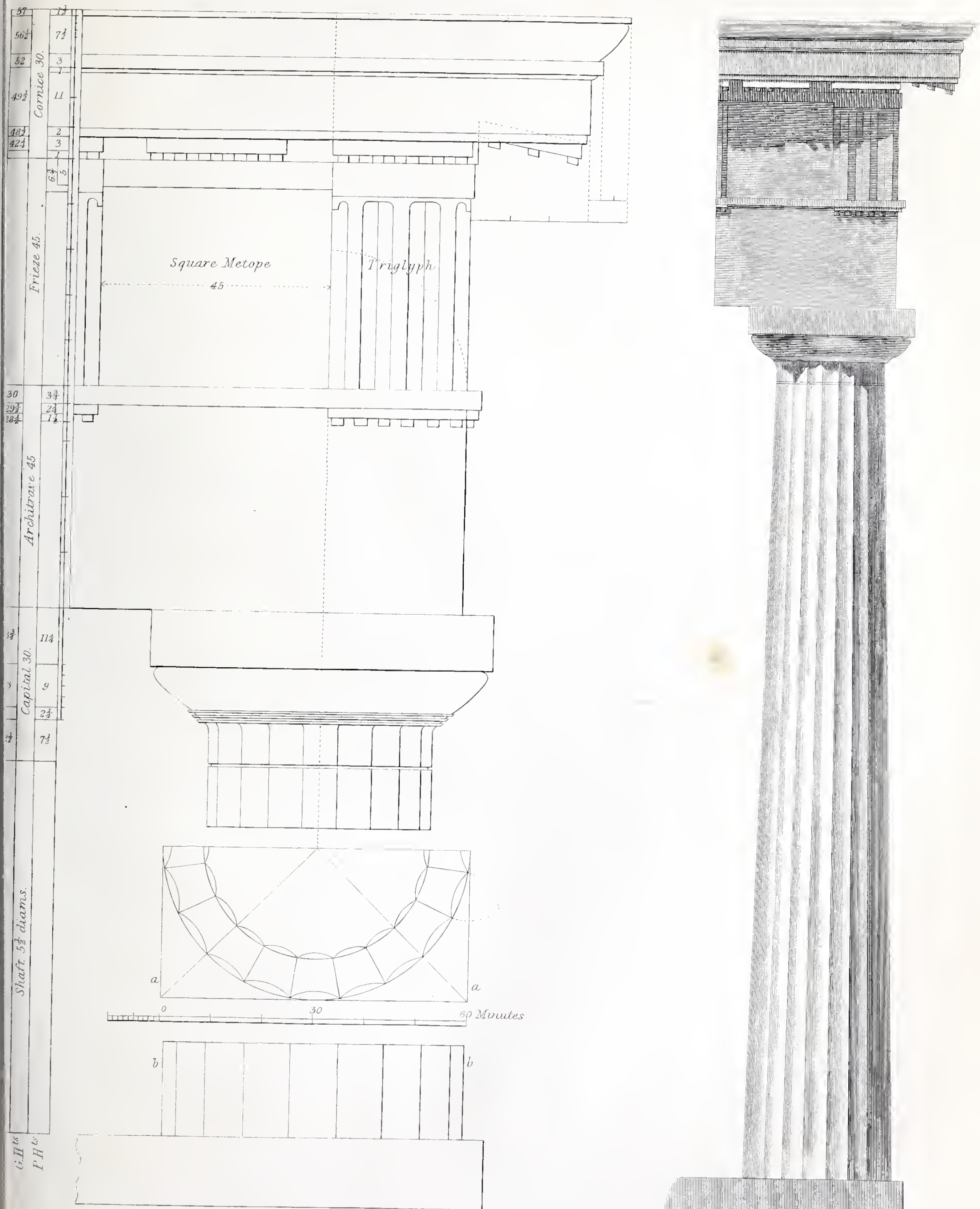
The architrave consists of one vertical face, with a continuous band or fillet at its upper edge; to the under side of this band are suspended a series of smaller fillets, with drops or guttæ; these fillets are of the same length as the breadth of the triglyphs in the frieze, and are placed exactly below them.

The frieze consists of rectangular projections and recesses placed alternately. The projections or tablets are diversified on the face by two vertical channels, and two half ones cut on the right and left edges, constituting three whole channels, and hence called Triglyphs. The square spaces alternating with the triglyphs, are named Metopes, and are frequently decorated with sculptures.

The cornice is distinguished by a conspicuous Corona, a term applied to a vertical or inclined plane surface which considerably overhangs the members underneath. To the corona, immediately over the

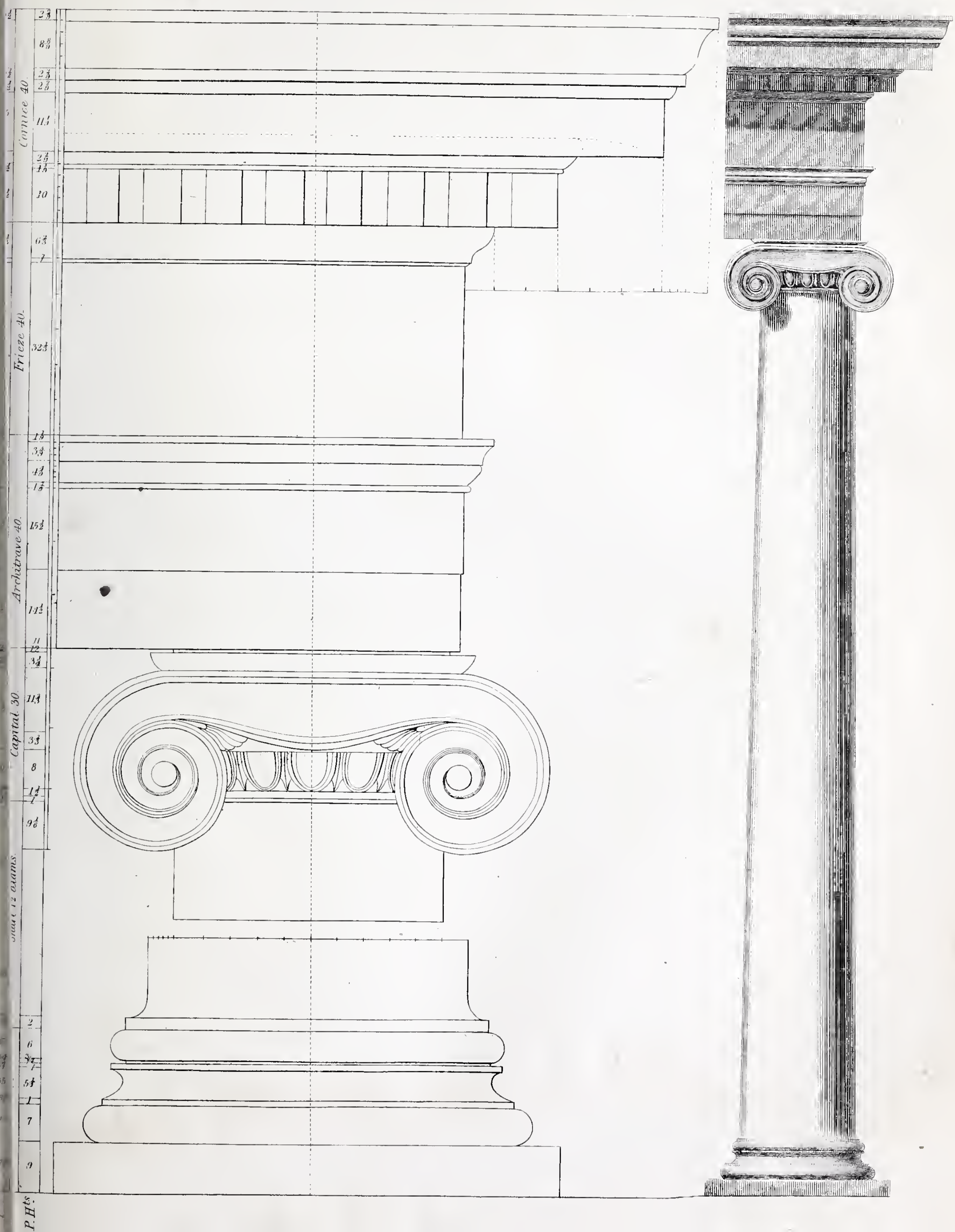
ORDERS OF ARCHITECTURE

GRECIAN DORIC ORDER.



ORDERS OF ARCHITECTURE

GRECIAN IONIC ORDER.



ORDERS OF ARCHITECTURE.

DETAILS OF IONIC ORDER.

Fig.1.

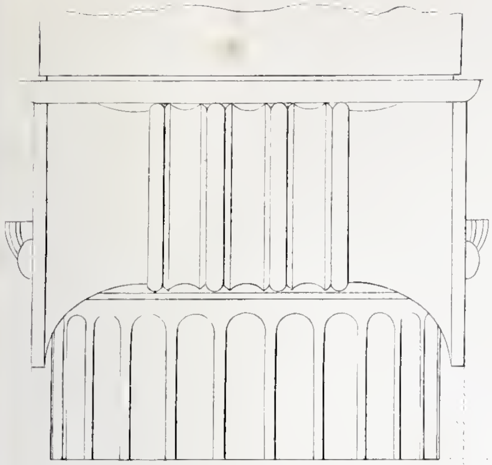


Fig.2.

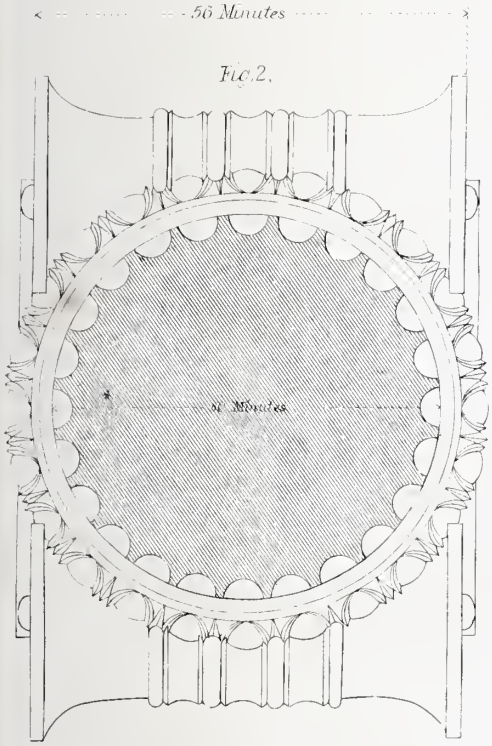


Fig 3.

Fig 4.

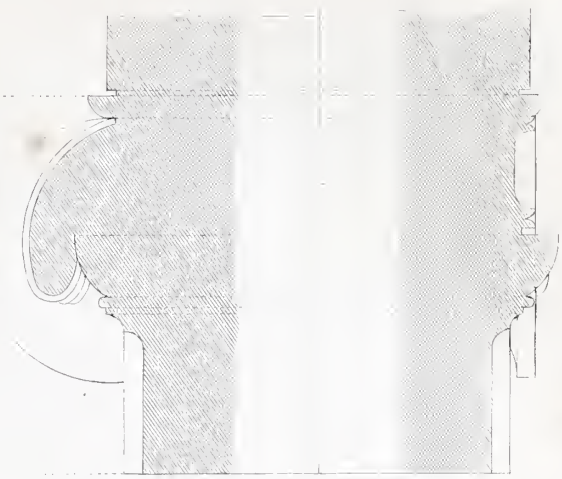


Fig.5.

Fig A.

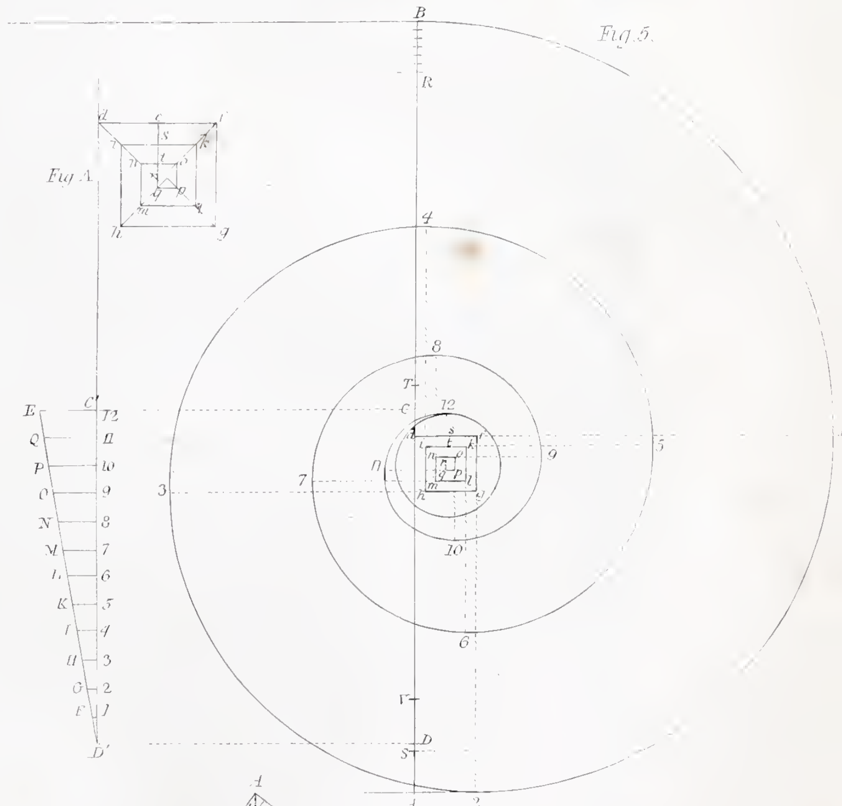


Fig 6.

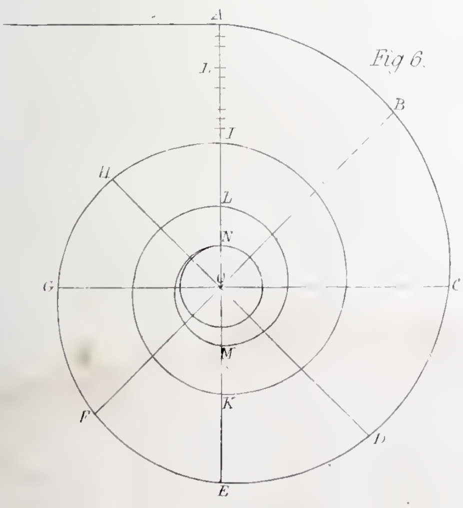
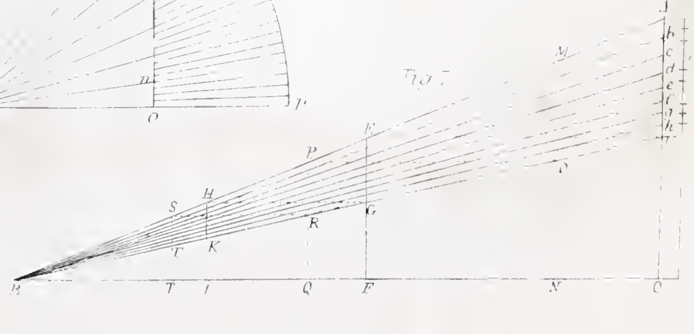


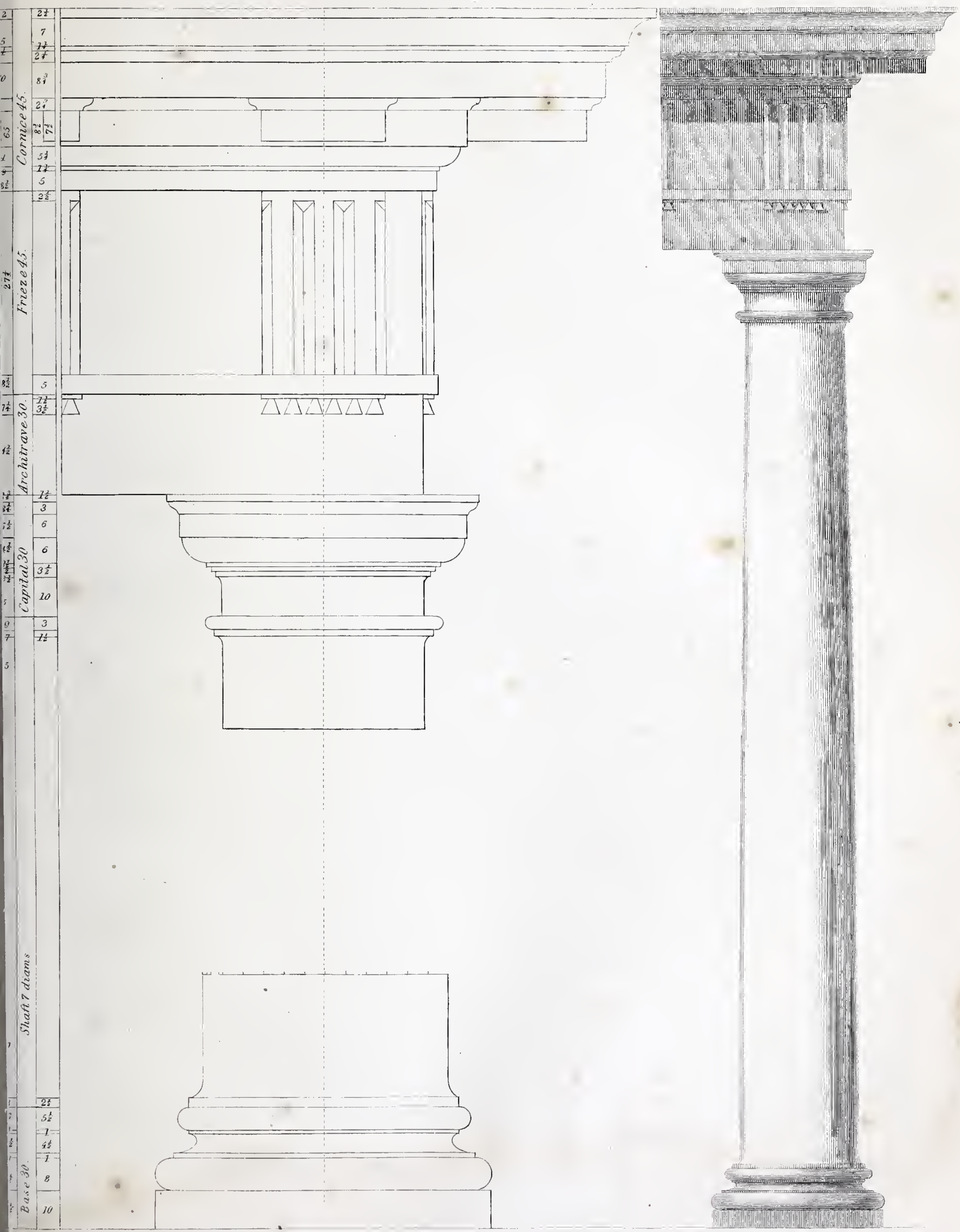
Fig 8.

Fig 7.



ORDERS OF ARCHITECTURE

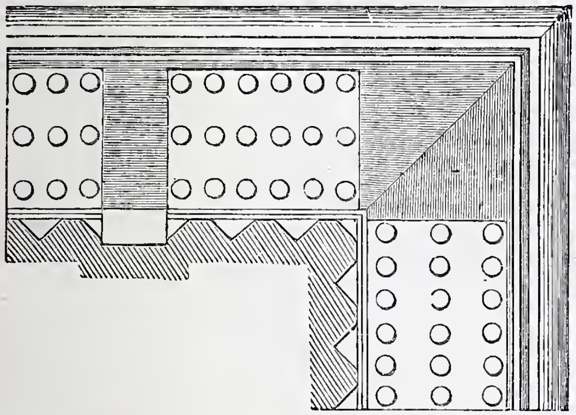
ROMAN DORIC ORDER.



triglyphs, blocks named Mutules are suspended, of which the soffit or under side is inclined downwards from the roof—the mutules are also furnished with guttæ or drops depending from their soffits.

The proportions of the different members of the Doric order, as practised by the Greeks, range within considerably wide limits. The following are the average proportions for the members of the order. Taking the diameter at the bottom of the shaft as the standard of measurement, the column is six diameters in height. The diameter at the upper end of the shaft is three-fourths of a diameter; that is, the shaft diminishes one-fourth of the diameter. The height of the capital is half a diameter; that of the ovolo, including the annulets, and that of the abacus, are each one quarter of the upper diameter, the annulets together being one-fifth of one of the parts. The horizontal dimension of the abacus is six times its height.

The height of the entablature is one-third of that of the column, or two diameters. If it be divided into 8 equal parts, these are distributed between the architrave, the frieze, and the cornice, in the proportion of 3, 3, 2: thus, the height of the architrave is equal to that of the frieze, and that of the cornice is two-thirds of either. The inner edge of the triglyph at the angle of the building is in a vertical line with the axis of the column; the breadth of the triglyph is three-fifths of its height, which is also that of the frieze, and the breadth being divided into nine equal parts, two are occupied by each glyph or channel, one by each semiglyph, and one by each of the three interglyphs or flat surfaces between the glyphs.



All this is shown in the annexed figure, which is a horizontal section of a portion of the entablature, viewed from below, and taken through the frieze. It exhibits the section of the triglyphs, as well as the arrangement of the mutules in the cornice, with their drops. The metopes are square; the height of the capital of the triglyph is one-seventh of its whole height, and that of the metope one-ninth. The height of the cornice being divided into five equal parts, the lowest is given to the fillet, the mutule, and the drops; the next two to the corona, and the remaining two parts are subdivided and disposed of, as shown in the detail figure, Plate II. The projection of the cornice over the capital of the triglyph is equal to its height; and being divided into four equal parts, three are given to the projection of the corona, and they are further subdivided as shown in the plate.

The number of annulets in the capital vary from three to five; and the number of horizontal grooves separating the shaft from the capital, vary from one to three.

In the scales which we have attached to the outline drawing of the order, three sets of dimensions are given, the nature of which are indicated by the initial letters at the bottom of the scales. The first scale contains the "particular heights" of all the members of the order, expressed in seconds, each figure standing opposite the member to which it refers. The second scale contains the "general heights" of the members, each division of the order being specified. The third scale contains the "projections" of all the particular members, beyond the centre line of the column, expressed in seconds.

OF THE GRECIAN IONIC ORDER.

The Ionic order, like the Doric, may be primarily divided into column and entablature; in its secondary divisions, however, a new element is introduced, as, besides the shaft, capital, architrave, frieze, and cornice, it is provided with a base to the column.

The origin of the Ionic order is problematical; its capital, which is its principal characteristic, has been compared to the curls in the head-dress of females, to the spiral horns of rams, the bark of some trees when dried in the sun, the form of various sea-shells, and so on. The order is a medium between the grave solidity of the doric, and the elegance and delicacy of the corinthian.

In the architrave and frieze, all appearances of triglyphs and guttæ are omitted; in the cornice, instead of the bold mutules of the doric, the ends of several pieces of wood are substituted, which are by way of support to the covering tiles, and are represented by dentils or teeth. The other portions of the cornice are analogous to those in the doric, and consist principally of a cyma, ovolo, and cornice. The great recess of the mouldings under the cornice gives it a striking prominence; this relieves its apparent heaviness, though both the dentil band and the cymatium of the frieze are introduced under it.

The base of the column consists of two tori, separated by a scotia, with fillets, and a square plinth, on which the column rests; though in some cases the plinth is dispensed with, and the column stands immediately upon the general platform which supports the whole.

In the volute of the capital, the lower edge of the channel which runs between the upper and under spirals, is formed into a curve bending downwards in the middle, and revolving about the spirals on both sides. The volute rests upon the ovolo, astragal and fillet, which terminate the shaft. The ovolo is always cut into eggs, surrounded by borders, with tongues between them. The shaft is in general cut into 24 flutes, with fillets between them, and the flutes are sometimes made with an elliptical section, which makes them flatter than when they are circular. The taper of the shaft is also less than that of the doric.

Besides the special dimensions given in plate III. of the Ionic order, the following may be noted as the general proportions of the order. The column is $8\frac{1}{2}$ diameters in height; the diameter of the upper end of the shaft is five-sixths of a diameter; the taper of the shaft is one-sixth. The height of the base, including the plinth, is half a diameter; the heights of the tori and the scotia are nearly equal; the upper fillet of the scotia projects as much as the upper torus. The projection of the lower torus beyond the lower radius of the shaft, is one-fifth of a diameter. The height of the capital is half a diameter; the height of the volute is seven-twelfths of a diameter; dividing the height of the volute into three equal parts, the top of the lower one reaches to the bottom of the ovolo, and the second division to the top of the festoon, on the axis of the column. The curvature of the outer spirals springs immediately from the ovolo with which the volute is crowned.

Dividing the whole height of the order into twenty-one parts, four of these go to the entablature, which is, therefore, two diameters in height; the height is equally distributed between the architrave, the frieze, and the cornice; dividing the height of the architrave into four parts, one part is due to the mouldings of the upper portion or capital; subdividing the capital into nine equal parts, give one to the upper fillet, three to the cavetto, four to the ovolo, and one to the bead. Divide the height of the frieze into six equal parts, and give the upper part to the talon, which forms the capital. Divide the cornice into three equal parts; subdivide the upper and lower thirds, each into six parts; in the upper third, give one part to the upper fillet, four to the cyma-recta, and one to the lower fillet, and turn one down into the middle third, for the ovolo under: dispose of the parts in the lower third as appears by the scale.

The projection of the cornice over the cymatium of the frieze is equal to its height; the projections of the subordinate members will be obvious at once from the scales attached.

We shall now give a more particular account of the construction of the volutes of Ionic capitals.

The volutes of this order are composed of two or more spirals of the same kind, which, after making a number of revolutions, terminate at the centre upon a central point resembling a button, denominated the eye of the volute. The spirals, which project from the surface to give them relief, are termed the *hems* of the volute; the interspaces being called the *channels*.

These definitions will be understood on referring to the detail drawings of the Ionic order, in Plates III and V. In Plate III, the front elevation of the capital is represented, showing the central eye, and the spirals terminating in it. The back elevation of the capital is the same as the front. The flanks, shown as side elevations in fig. 1, Plate V, have somewhat the appearance of a balustre. In the plan, fig. 2, this portion of the capital, supposed to be viewed from the under side, appears square in its general outline. Fig. 3, is a vertical section of the capital, exhibiting the profile in flank; fig. 4, is a vertical section drawn to the same centre line, and in a plane at right angles to that of the preceding section,

exhibiting the contour of the front and back elevations of the capital. From these figures it will be observed that the volutes fit like a cap upon the circular tablet formed by the ovolo. There are no precise rules for the form of the capital in flank, except, perhaps, that the parallel beads which decorate the scroll should run directly into the interspaces of the carvings upon the ovolo; otherwise, the configuration of the parts is left to the taste of the designer. The shaft of the column has been represented fluted in these details, that the correspondence of the flutes with the carvings upon the ovolo may be shown.

To describe the simplest form of volute, which consists of two spirals, and is represented in Plate III, of the Ionic Order, the following simple and accurate process, first practised by Mr P. Nicholson, may be adopted.

To describe the Ionic volute: the number of revolutions or quarters of which the spirals are to consist being given, the vertical height, also, of the spiral, and the diameter of the eye: Let A B, Plate V, fig. 5, be the height of the volute, and let the spiral make three revolutions, consisting, therefore, of 12 quarters; bisect A B at the point e, and from A B cut off A D, equal to the given radius of the eye; divide D e into as many equal parts as there are quarter revolutions in the spiral to be drawn, (which in this case are twelve in number), at the points 1, 2, 3, ... 11, 12. To prevent confusion, we have indicated this division upon a parallel line D′ C′; draw C E at any angle with C D, and make it equal to two of these parts; join D E, and from the points 1, 2, 3, ... draw straight lines 1 F, 2 G, 3 H, ... parallel to e E; taking c d equal to one part, draw $d\,f$ perpendicular to A B, and equal to 12 E; draw $f\,g$ perpendicular to $d\,f$, and equal to 11 Q; draw again $g\,h$ perpendicular to $f\,g$, and equal to 10 P. Proceed in this manner until all the sides of this winding fret-work are drawn; then, the points $d, f, g, \ldots p, q, r$, so found, are the centres from which the quadrants which compose the spiral must be successively described. For this purpose, produce $d\,f$ to 1, $f\,g$ to 2, $g\,h$ to 3, and so on; the quadrants, as they are described, will be limited by these lines; from the centre d, with the radius d B, describe the quadrant B 1; from the centre f, with the radius f, describe the quadrant 1, 2; from g, with the radius g 2, describe in like manner the quadrant 2, 3; and proceed in this way till the last arc, 11, 12, is described from the centre q, with the radius q 11; then, finally, describe the circle at the centre from the point r, and with the radius r 12. If the operation be accurately performed, this radius, r 12, will be equal to A D, as required, and the spiral line will be completed.

But, as the process, as it is now described, is very liable to inaccuracy, the method of finding the centres shown on a larger scale at fig. A, is at once more expeditious and more certain. Having drawn $d\,f$ perpendicular to the vertical line, bisect it at e; draw $e\,r$ perpendicular to $d\,f$, equal to $d\,e$ or $e\,f$, and join $d\,r$ and $f\,r$; divide $e\,r$ into three equal parts, $e\,s$, $s\,t$, $t\,r$, and draw $i\,s\,k$ and $n\,t\,o$ parallel to $d\,f$; draw $f\,g$ perpendicular to $d\,f$, and equal to 11 Q; draw $g\,h$ and $i\,h$ respectively parallel and perpendicular to $d\,f$, meeting at the point h; draw the diagonals $g\,p$ and $h\,q$ parallel to $d\,r$ and $f\,r$, and draw the perpendiculars $k\,l$, $o\,p$, $r\,q$, $n\,m$. In this way all the centres are determined, namely, $d, f, g, h, \ldots o, p, q, r$.

To describe the second spiral line, which, with the first one, comprehends the thickness of the hem, a similar process is applicable. Set off B R for the thickness of the hem at that part, and, supposing the hem to diminish in thickness by equal amounts for each half revolution, divide B R into six equal parts; as the spiral describes six half revolutions, it will diminish in thickness one-sixth of B R for each half revolution; set off, therefore, A S equal to 5-6ths of B R, then R S is the height of the second spiral. Bisect R S at T, and set off S V equal to the radius of the eye; then, dividing T V into 12 equal parts, the method already described for finding the centres may be applied.

The method already described, though it is well adapted to the description of the single spiral, is not applicable where there are many spirals. In this case, the principle of the logarithmic spiral may be employed. The nature of this spiral is such, that being divided into equal angular segments, as quadrants or half quadrants, its distances from the centre, at the ends of the segments successively, decrease in a geometrical ratio.

To describe the Ionic volute, on the principle of the logarithmic spiral: the centre, the vertical height, and the distance between the first and second revolutions of the outer spiral being given.

Definition.—The vertical line O A, fig. 6, drawn from the centre O of the spiral, and expressing also the height of it above the centre, is termed the *cathetus.*

If then O A be the cathetus, O, the centre, and A I the distance between the first and second revolutions, produce A O to E, and draw G O e at right angles to A E; bisect the angles at the centre by the straight lines B O F and D O H; find a mean geometrical proportional between O A and O I, and make O E equal to it; find also a mean proportional between O A and O E, and make O C equal to this mean. Having thus found the consecutive points A, B, and C, the distances of which from the centre are in geometrical progression, the others in succession will be found by the aid of proportional compasses. Having set the compasses, so that the ratio of the lengths of the legs on the opposite sides of the centre pin may be that of O A to O B, it is obvious that if the distance A O be taken between the longer ends, the shorter ends will measure the distance B O; and, in like manner, that if the longer ends be set to B O, the shorter ends will measure e O. Farther, by taking e O in the one end, we have D O in the other; and proceeding in this way, we may find successively the distances E O, F O, G O, &c., which furnish as many points in the spiral; and, by tracing a curve line through the points thus found, the spiral will be completed. The divisions marked off upon the line A G indicate the commencements of the other spirals, of which the volute consists, which are disposed in three sets.

Another method of setting off the spiral by means of proportional compasses, without pricking the paper, is to construct a scale of parts A B O, fig. 7. This method also expedites the process considerably. Having found O A and O B, as before, and set the compasses in the manner already described, make O A, fig. 7, equal to O A, fig. 6, by the longer ends of the compasses, and mark off O b, the distance between the shorter ends. Take again O b, between the longer ends, and mark O c, between the short ends; similarly, from O c find O d, and so on, till the the distance O i, is found. And here the accuracy of the process may be tested, as O i, fig. 7, should be equal to O I, fig. 6. Join the points of division in A i to the point B; draw the horizontal line i E, and from E draw the vertical E F, cutting i B at the point G; draw again the horizontal and vertical lines G H and H K I. Then the the three scales A O, E F and H I, will afford eight points in each of the three revolutions of the first spiral A E G I: O b is equal to O B, O c equal to O e, O d equal to O D, and so on; and lastly, O i or F E is equal to O I. Following the same process, the eight divisions on the scale F E give eight points in the second revolution I K L, and the scale I H gives eight points to the third revolution L M N.

The points thus determined for the spiral may be transferred to the edge of a slip of paper, and thence marked by a pencil point upon the drawing, fig. 6.

The same scale, fig. 7, may be employed for the other spiral lines in the volute, the commencements of which are marked on the line A I, fig. 6, for, by dividing the parallel line A i, which is equal to A I, in the same manner as A I, and drawing horizontal lines from these several points of division, as indicated in the figure by dot lines, the perpendiculars drawn from the points at which these lines meet A B, furnish scales for their first revolutions respectively. For example, if we draw a horizontal line L M from the point L, meeting A B at the point M, the perpendicular M O N becomes a scale of parts for setting off the first revolution of the spiral which starts at the same point L, fig 6. The scales P R Q and S U T, formed in the same manner as before, serve to define the second and third revolutions of the same spiral. In this way, then, it is clear we can readily construct a set of scales for each individual spiral.

Another mode of finding a series of points in a spiral is represented by the scale, fig. 8, for which we are indebted to an elementary publication on Architecture.

Referring for convenience to fig. 6, divide the whole height A E into 16 equal parts, making the portion A O above the centre equal to 9 parts, and leaving of course 7 for the portion O E. In fig. 8, make O E equal to O E, fig. 6, and draw a perpendicular O A equal to O A, fig. 6; join A E, and on E as a centre describe the arc A P; divide that arc into 28 equal parts, and join the points of division to the centre E. The straight line A O intersected by these radii at the points b, c, d, &c., forms the scale for the first spiral: thus O A is the distance O A, fig. 6; O b gives the distance O B, O c gives the distance O e; O d gives the distance O D, and so on, till lastly O n gives the radius O N of the eye, which is described by a circle on the centre O. Having thus marked off a series of points in the curve, it may be completed either by describing arcs of circles connecting the points which have been set off, or by tracing by hand a curve line through them. The other spiral lines of the volute may be described in like manner by making a new scale for each.

In this example, the radius of the eye has been made equal to the first four divisions of the line A, the remaining 24 divisions being distributed along the spiral. We may, of course, secure any number of divisions for the radius of the eye; if we are to secure 8 divisions, for example, then as 24 are due to the spiral, the arc must be divided into 24 + 8 or 32 parts.

INSTRUMENT FOR DETERMINING THE SPEED OF SHIPS AT SEA.

The instrument, of which a sketch is annexed, is the invention of Mr. J. S. Brown, and is intended to be used for ascertaining the speed of ships at sea. It consists of a copper wheel, B, figs. 1 and 2, about two inches in diameter, with a vane, *e*, fig. 2, like that of a windmill. The axis, D, of this wheel, is made into a fine-threaded screw; a piece of copper wire, D D,

Fig. 1.

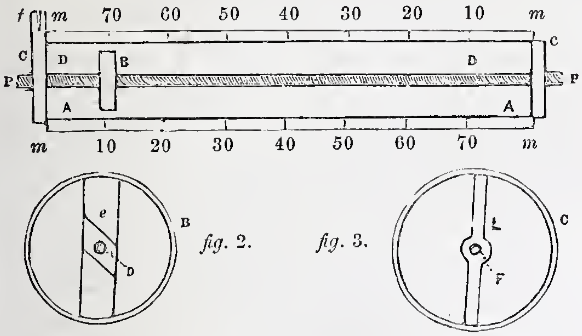


fig. 1, (about a foot long,) is also made into a screw, to screw into the axis of the wheel, D, fig. 2. This wire is held in the centre of the cylinder, A A, fig. 1, of glass or metal, (if the latter, it should have a strip of glass fixed to it that the position of the wheel may be seen,) by cross pieces fitted to the ends of the cylinder, and shown at L, fig. 3. The piece at each end of the cylinder has two rings, C C, fig. 1, and C, fig. 3, soldered to them; this keeps the pieces, L, (into which the wire, D D, fig. 1, screws,) secure and immovable, as the rings, C C, fig. 1, and C, fig. 3, cover a small part of the cylinder. A strong screw is attached to the instrument at *f*, fig. 1; and the scales *m*, *m*, *m*, *m*, fig. 1, increase in numbers in opposite directions; thus permitting the instrument to be used with facility when the wheel B is at either end of the cylinder.

It is evident, from this arrangement, that if any power act on the vanes of the wheel, it will revolve; but the wheel cannot revolve, without at the same time traversing the wire by the action of the screw; or, in other words, when the wheel revolves, it at the same time screws itself along the wire in a direction depending upon the position of the angle at which the vanes are placed in regard to the screw; and it is upon this double motion of the wheel that the mariner is able to ascertain how fast the ship is sailing. Supposing that, when a vessel is sailing at the rate of from five to ten miles an hour, the instrument is held under water, from the deck of tho ship, at the end of a pole, screwed to *f*, fig. 1, with either end of the cylinder in the direction in which the ship is sailing, the water passing in a current through the cylinder will cause the wheel to revolve and traverse over the wire with a speed in proportion to the strength of the current affecting the instrument, while this depends upon the rate at which the ship is actually sailing.

In the model constructed by the inventor, the vanes are placed at an angle with the screw, which causes the wheel when revolving to travel against the current of water passing through the cylinder, and, of course, the power exerted on the various vanes must be such as to cause the instrument to overcome the pressure of the water against the substance of the wheel. This model has been in a boat on a canal, and it answered perfectly well when the boat travelled about five miles an hour, but it would not act when the boat went slow. The instrument, thus constructed, is therefore adapted for ships under full sail; but another wheel, with the angles of the vanes in an opposite direction, (so that the wheel when revolving would travel with, and not against, the current as in the preceding,) might act with the slowest motion or current of water through the cylinder.

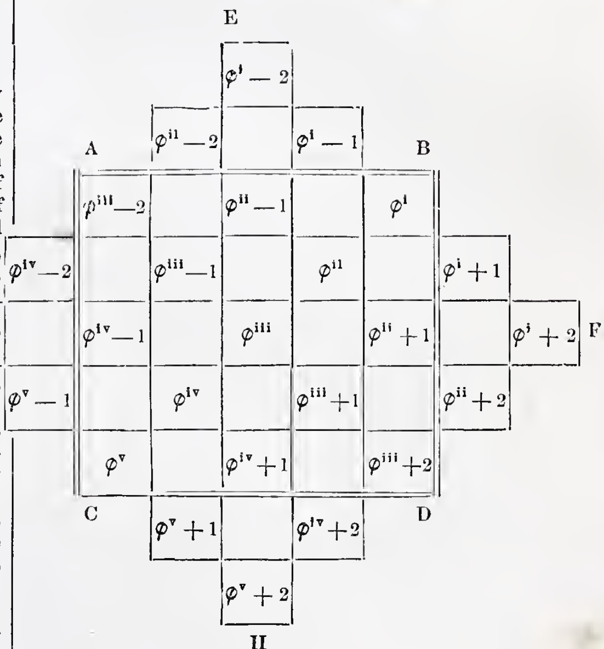
MAGIC SQUARES.

Let a square A B D C be constructed on any uneven number, n, as a root, and about it another whose side shall be parallel to the diagonal of the former, in a manner obvious from an inspection of the annexed diagram.

Inscribe in this outer or diagonal square the series of natural numbers, commencing at the top E, and proceeding along the row E F and those parallel to it, in regular succession, till all the numbers in n^2 are inscribed. Then let every number occupying a cell beyond the inner square be removed into it, by transferring it n cells in a vertical or horizontal direction from its first position, the numbers in the inner square will then be so arranged that the sum of every column, whether vertical or horizontal, and also of both diagonals, will be of the same amount.

And first, it is obvious that every number so carried into the inner square will find a vacant cell to receive it; for every number, as originally inscribed, has a vacant cell immediately adjoining it, both vertically and horizontally; and therefore, reckoning from any number as first placed, there is a vacancy in every alternate cell corresponding to the odd numbers—but n being an odd number, every figure requiring to be transferred must have a cell for it empty at n places distant from its original position.

Now, the middle number of the first row E F being the middle



term of the n first natural numbers is $\frac{n+1}{2}$ and forms the first number in the diagonal B C of the inner square. The second number in B C is $\frac{n+1}{2}+n$ or $\frac{3n+1}{2}$; the third $\frac{5n+1}{2}$ and so on. But the diagonal B C is the central column of the outer square, and has an equal number of parallel columns on each side, the numbers in which may be represented by the symbols for those in the central column, adding or subtracting 1, 2, 3,... $\frac{n-1}{2}$; so that every number in n^2 will be represented by one term of one of the two following series, associated with one term of the other, viz:—

$$\frac{n+1}{2},\ \frac{3n+1}{2},\ \frac{5n+1}{2},\ \ldots\ldots\ldots\ \frac{n(2n-1)+1}{2}$$

$$-\frac{n-1}{2},\ \ldots\ \ -2, -1, 0, 1, 2,\ \ldots\ldots\ \frac{n-1}{2}$$

The row E F, when transferred to the inner square, will traverse it diagonally throughout its whole height and breadth; and therefore every column of the inner square, whether vertical or horizontal, must contain one term of the row E F. Every such column,

therefore, must contain the first term of the first series associated with some term of the second series.

The same holds of the next row parallel to E F; and therefore, the second term of the first series must he found in every column of the inner square, whether vertical or horizontal,—and so of every succeeding row. Again, the row E G, of the outer square, will be found traversing the inner square diagonally, through its whole extent; and therefore, the first term of the second series, associated with some term of the first series must be found in every column, whether vertical or horizontal; and so also of every row parallel to E O.

Thus it appears that every column of the inner square must contain every term of the first series, and likewise every term of the second series, and therefore the sum of the numbers in every such column must be equal to the united sums of both series. But the sum of the second series is 0, and the sum of the first is $\frac{n\,(n^2+1)}{2}$; this therefore is the sum of each column.

The diagonal B C being composed of the terms of the first series is obviously of the same amount. The other diagonal A D, being composed of the n middle numbers in n^2, is equal to the middle number in n^2, and the same associated with $\pm 1, \pm 2 \ldots \pm \frac{n-1}{2}$ But the middle number in n^2 is $\frac{n^2+1}{2}$; the sum of the numbers in this diagonal is therefore $n\left(\frac{n^2+1}{2}\right)$ as before. Any of the columns may be transferred to another position, provided it be carried parallel to itself, and thus an almost endless variety of squares constructed on the same root without altering the result, except as regards the diagonals.

Supposing the horizontal rows to remain unaltered, the vertical ones may be changed $1 \times 2 \times 3 \;.\;.\;. \times n$, ways; and as each of these arrangements may be made a starting point for like permutations on the horizontal rows, the total number will be $(1 \times 2 \times 3 \;.\;.\;. \times n)^2$. In the case of the root eleven, this is 39916800^2.

The mechanical arrangement, by which squares are formed on an odd base, will not apply to those on an even number, for want of a central column; nevertheless the foregoing considerations will suffice to suggest how squares may be constructed on even roots as well as uneven.

The numbers in n^2 being divided into periods of n numbers each, and the numbers in each period represented by a term of the series $\frac{n+1}{2}$, $\frac{3n+1}{2}$, $\frac{5n+1}{2}$, &c., associated (when n is an even number) with $\pm \frac{1}{2}$, $\pm \frac{3}{2}$, $\pm \frac{5}{2}$, &c., the problem is simply how to have every column contain numbers whereof the sum of the terms taken from the first series shall be $\frac{n(n^2+1)}{2}$ and the sum of terms taken from the second equal to 0. This latter condition is fulfilled by taking the terms of like numerical value alternately affected with opposite signs; and the former condition may be reached by the following consideration, viz., in any arithmetical progression, the sum of two terms, equidistant from both extremes, is constant; and this sum, multiplied by half the number of terms, is equal to the sum of the series.

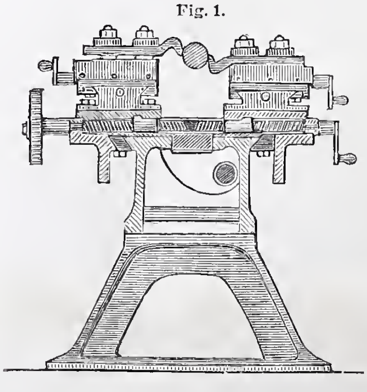
If, therefore, in the horizontal columns, we write all the terms of the first series in succession, and append to them, in the same column, the same number from the second series, affected with opposite signs alternately, it is clear that the sum of every horizontal column, being the sum of all the terms in the first series, must be $\frac{n(n^2+1)}{2}$. Again, if the terms (ϕ) in the horizontal rows be continued in the same order for the first $\frac{n}{2}$ rows, and then be exactly reversed for the last $\frac{n}{2}$ rows, we shall have in each vertical column two suplemental terms repeated each $\frac{n}{2}$ times, and the sum of the column will therefore be $\frac{n(n^2+1)}{2}$, provided the numerical adjuncts neutralize each other, which will always be the case when $\frac{n}{2}$ is an even number; but when $\frac{n}{2}$ is an odd number, no magic square can be constructed on n. For the number of terms in the series (ϕ) being even, every pair of supplemental terms will occupy, the one an odd, and the other an even place; and, therefore, when inscribed in the same horizontal row, the adjunct of the one will he affected with the positive, and that of the other with the negative sign. Hence it follows, that in the vertical columns the adjuncts of the same term (ϕ) must balance each other irrespectively of those of its supplemental term; but when $\frac{n}{2}$ is an odd number, this is impossible, because the sum of an odd number of the adjunct is fractional, and the sum of an even number is an integer. So that a magic square cannot be constructed on an even root n, unless $\frac{n}{2}$ be also even.

The inspection of an example represented by general symbols will render the arrangement obvious at once.

$\phi^{i}+\frac{1}{2}$	$\phi^{ii}-\frac{1}{2}$	$\phi^{iii}+\frac{1}{2}$	$\phi^{iv}-\frac{1}{2}$	$\phi^{v}+\frac{1}{2}$	$\phi^{vi}-\frac{1}{2}$	$\phi^{vii}+\frac{1}{2}$	$\phi^{viii}-\frac{1}{2}$
$\phi^{i}-\frac{1}{2}$	$\phi^{ii}+\frac{1}{2}$	$\phi^{iii}-\frac{1}{2}$	$\phi^{iv}+\frac{1}{2}$	$\phi^{v}-\frac{1}{2}$	$\phi^{vi}+\frac{1}{2}$	$\phi^{vii}-\frac{1}{2}$	$\phi^{viii}+\frac{1}{2}$
$\phi^{i}+\frac{3}{2}$	$\phi^{ii}-\frac{3}{2}$	$\phi^{iii}+\frac{3}{2}$	$\phi^{iv}-\frac{3}{2}$	$\phi^{v}+\frac{3}{2}$	$\phi^{vi}-\frac{3}{2}$	$\phi^{vii}+\frac{3}{2}$	$\phi^{viii}-\frac{3}{2}$
$\phi^{i}-\frac{3}{2}$	$\phi^{ii}+\frac{3}{2}$	$\phi^{iii}-\frac{3}{2}$	$\phi^{iv}+\frac{3}{2}$	$\phi^{v}-\frac{3}{2}$	$\phi^{vi}+\frac{3}{2}$	$\phi^{vii}-\frac{3}{2}$	$\phi^{viii}+\frac{3}{2}$
$\phi^{viii}+\frac{5}{2}$	$\phi^{vii}-\frac{5}{2}$	$\phi^{vi}+\frac{5}{2}$	$\phi^{v}-\frac{5}{2}$	$\phi^{iv}+\frac{5}{2}$	$\phi^{iii}-\frac{5}{2}$	$\phi^{ii}+\frac{5}{2}$	$\phi^{i}-\frac{5}{2}$
$\phi^{viii}-\frac{5}{2}$	$\phi^{vii}+\frac{5}{2}$	$\phi^{vi}-\frac{5}{2}$	$\phi^{v}+\frac{5}{2}$	$\phi^{iv}-\frac{5}{2}$	$\phi^{iii}+\frac{5}{2}$	$\phi^{ii}-\frac{5}{2}$	$\phi^{i}+\frac{5}{2}$
$\phi^{viii}+\frac{7}{2}$	$\phi^{vii}-\frac{7}{2}$	$\phi^{vi}+\frac{7}{2}$	$\phi^{v}-\frac{7}{2}$	$\phi^{iv}+\frac{7}{2}$	$\phi^{iii}-\frac{7}{2}$	$\phi^{ii}+\frac{7}{2}$	$\phi^{i}-\frac{7}{2}$
$\phi^{viii}-\frac{7}{2}$	$\phi^{vii}-\frac{7}{2}$	$\phi^{vi}-\frac{7}{2}$	$\phi^{v}+\frac{7}{2}$	$\phi^{iv}-\frac{7}{2}$	$\phi^{iii}+\frac{7}{2}$	$\phi^{ii}-\frac{7}{2}$	$\phi^{i}+\frac{7}{2}$

WHITWORTH'S SELF-ACTING TOOLS.

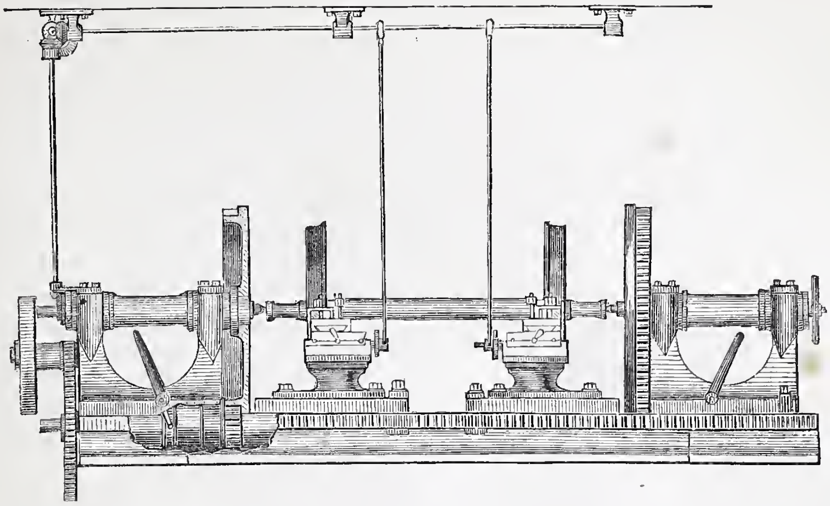
Fig. 1.



WHITWORTH'S patent self-acting duplex lathe is shown in the annexed sketch, fig. 1. The duplex principle consists in the employment of a cutting tool at the back of the lathe, opposite to the tool in front, and in inverted positions to each other. The transverse forces are thus balanced, the work produced is more correct, and is accomplished in less time than by the ordinary

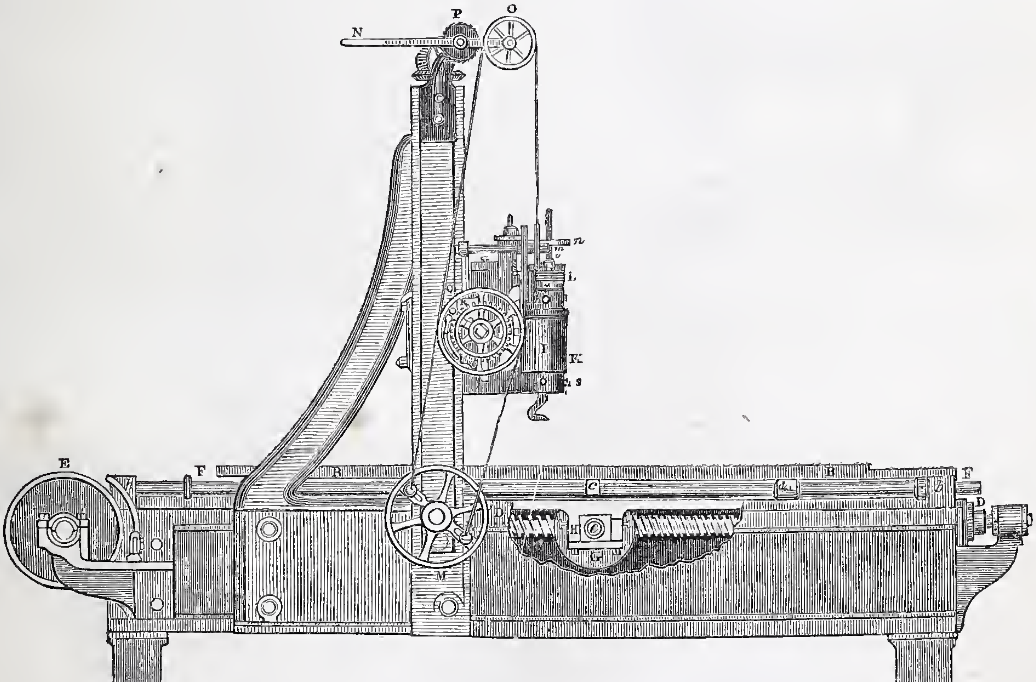
lathe. The machine represented in fig. 1 is furnished accordingly with two cutting tools, arranged as above stated, for sliding, screwing, and surfacing; having double geared head-stocks, with conical steel mandrel and bearings. The other features of this machine are as follow:—Slide-rest, with quick hand traverse; two compound top rests, one on each side of the lathe centres, with independent adjustments; two extra slides, with right and left screw for working the top rests simultaneously; guide screw, disengaging nut, and twenty-three change wheels for screw-cutting; two face plates, elements driver, drill, and bell chucks.

Fig. 2.



Whitworth's patent self-acting compound duplex lathe, with four cutting tools, for sliding, screwing, and surfacing, is similar to the foregoing, except that the compound lathe has a duplicate independent series of self-acting motions and tools, which may either be worked separately or simultaneously.

Fig. 3.



The bed is of great length, in one casting, and may be used for two distinct lathes, by employing an extra set of head-stocks. The lathe, though suited for general work, is intended more particularly for sliding long shafting, and for cutting screws. In sliding a shaft, the two series of tools commence in the middle of its length, and proceed in a direction

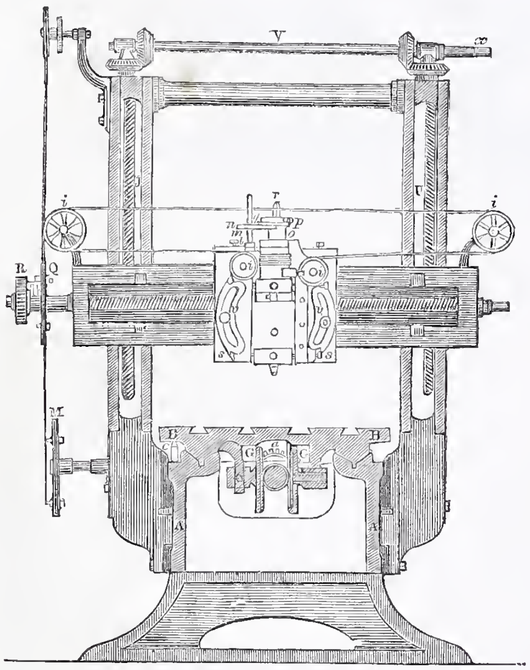
right and left. There is, consequently, a balance of force longitudinally, as well as transversely.

Whitworth's patent self-acting duplex railway-wheel turning-lathe is represented in fig. 2. This machine includes two sets of double-geared headstocks and face-plates, driven independently, to prevent torsion of the axle; four compound slide-rests, with separate self-acting motions to each, and swivel plates. Four cutting tools are employed, two acting upon opposite sides of each wheel. Both wheels are turned at once upon their axle, and the slide-rests are readily removeable, in order to get the wheels into and out of the lathe.

Another machine, patented and manufactured by the same firm, is the self-acting planing machine, to plane one way, with quick return motion.

Also, the patent self-acting planing machine, with reversing tool, to plane both ways. This machine, which is represented in figs. 3 and 4, is designed for general work of moderate size. Its principal peculiarities consist in the modes adopted to move the table, and to reverse the tool, by which the machine planes both ways.

Fig. 4.



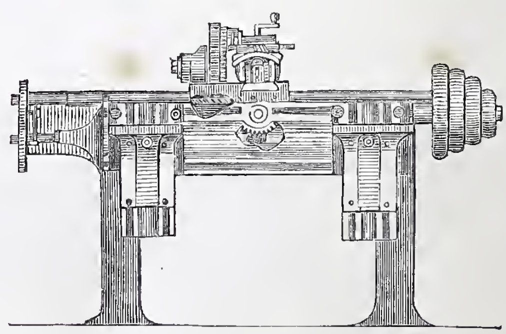
The bed-frame A A of the machine is of cast-iron, and has its upper edges formed into angular bearings, upon which the table B B slides. These bearings are provided with self-oiling apparatus, which keeps their sides well lubricated during the working of the machine. The table is ribbed on the under side to give it strength, and has dovetail grooves on the upper side for fixing the work. The table is moved by a strong wrought-iron screw C, which revolves under it in end bearings D, and at other points of its length when the machine is very long. At the end of the machine at which the driving gear is placed, a bevel wheel *a* is fixed upon the screw; this wheel is driven alternately in opposite directions by two smaller bevel wheels, connected with the pulleys E by a long boss and interior shaft. The driving belt is passed from one pulley to the other, by a bell-crank lever and guide, worked by two pins on the horizontal rod F F, which extends the whole length of the machine, and slides in supports *b b* upon the bed-frame. A fixed stop *c* upon the table comes in contact, during the travel of the table, with the moveable stops *d* (only one of which is seen in fig. 4), and moves the rod F F in the direction of its length, making the pins upon it move the reversing crank, thus causing the belt to pass from one pulley to the other, thereby reversing the motion of the screw. The reciprocating motion of the screw is communicated to the table by a pair of guide discs G G, the peripheries of which are formed with flanges at right angles to the planes of the discs; these flanges work into the screw, and the discs, which are placed parallel to each other, have their axes *e* in bearings H H, firmly attached to the under side of the centre of the table. Each periphery of the discs has two opposite points of contact, which act alternately upon the inner sides of the thread of the screw. The screw, as it turns either way, brings its threads to bear against the flanges of the discs, causing them to revolve, and at the same time carrying the table forward in obedience to the motion of the screw.

By this beautiful contrivance, which was patented by Mr. Whitworth in 1835, the friction is transferred from the screw to the axes of the discs, where the velocity is reduced in the proportion of the periphery of the disc to the circumference of its axis. This proportion is about seven to one. To avoid the friction which would arise between the parts in contact (thread and flange) from the different velocities of the thread at different distances from the centre, both the thread of the screw and the flanges are slightly bevelled. Holes are drilled from the top of the table into the bearings for oiling the axes; these axes are case-hardened, and revolve in case-hardened bushes of considerable length. Access is afforded to the guide discs by a rectangular opening in the table, covered by a plate, which may be removed at pleasure. The discs are adjusted by set screws acting on their bearings.

This arrangement allows of a perfectly uniform motion of the table, which cannot easily be attained with a chain or rack, and which is of the utmost importance to the proper action of the tool. It also admits of a great simplicity of the driving parts, the gearing ordinarily introduced to reduce velocity being superseded by the screw itself, which directly converts the high velocity of revolution communicated to it into rectilinear motion of the requisite intensity. Thus, if the pitch of the screw be one inch, and its diameter two inches, the power of the screw alone is sixfold, and the table will move through one inch at each revolution.

The machine, as already stated, planes both ways. This is effected by an arrangement, whereby the tool is made to turn round at the end of each cut, at the same instant that the table is being reversed. The parts consist of a socket I, fig. 4, which revolves in a conical bearing K, attached to the vertical slide *g*. On the upper end of the socket is a pulley L, fixed to it by a screw-pin *h*; round this pulley a band passes twice, and gives it the reversing action in connection with the reversing wheel M, to which it passes over the guide pulleys *i i i*, attached to the horizontal and vertical slides. These pulleys give the proper direction to the band, in all the varying positions of the slides, and keep it always on the socket pulley L, at whatever angle the tool-holder may be placed. The proper tension is given to the band by the lever N, at the top of the upright frame, which carries a pulley O, on one side of its fulcrum, round which the band passes; and a ratchet on the other side of the fulcrum, which takes into a fixed wheel P.

Fig. 5.

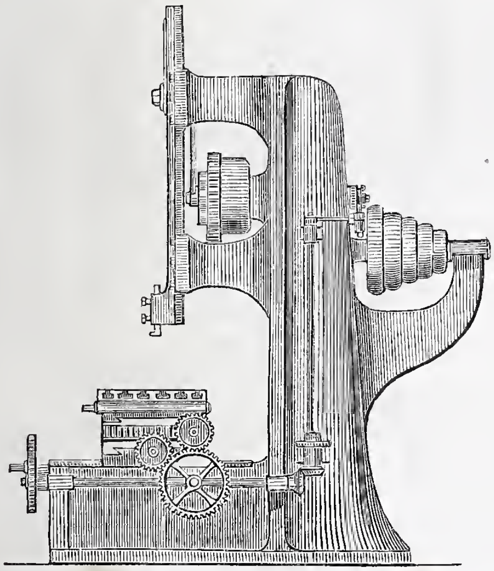


Motion is given to the reversing wheel M, and transmitted through the band to the socket of the tool, by a rack on the horizontal rod F F, which gears into a pinion on the axis of the wheel M. On the same axis is sometimes placed a cam, against which the end of a weighted lever is made to bear, in such a way that the weight shall tend to maintain the position of the wheel M during the travel of the table. The motion of the rod F F, given by the table, serves thus at the same instant to shift the driving-belt and work the reversing band, by which the socket is made to perform half a revolution, and bring the tool into the reverse position. To determine the precise position of the tool, a stop is fixed upon the down slide, with which a projecting piece on the socket pulley comes into contact. This stop also serves to support the tool against the work in cutting.

The reversing band passes round a loose pulley Q; this pulley works a fixed ratchet-wheel R, on the end of the horizontal screw S S, by means of a click. By this arrangement, motion is given to the screw S S, which it communicates to the tool carriage by means of nuts in the ordinary way, thereby causing the tool to work slowly across the table.

For the down motion of the cutter, an arm, projecting from the socket pulley L, carries an upright screw-pin *m*, which works in a slot in the lever *n*, upon the fixed washer *o*, which embraces the screw of the down slide *g*. A ratchet on the lever, taking into a wheel on the screw, gives the down motion, and renders it also self-acting at any angle of the tool. The same lever *n* carries a pin, which may be made to act as a

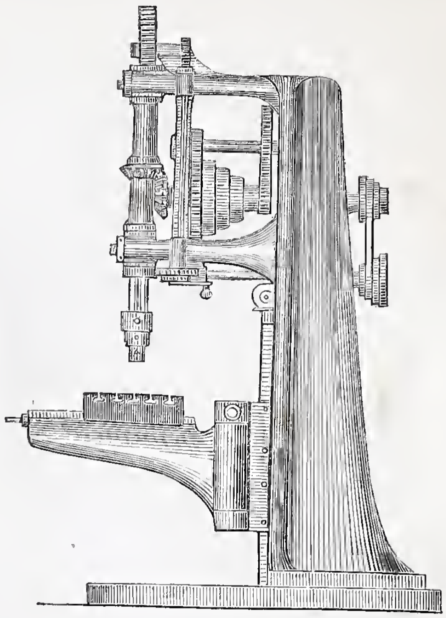
Fig. 6.



clasp round the screw T, to relieve the tool when the reversing motion cannot be employed, as in planing up to a stop. In this case the screw-pin *h* is removed, and the socket is fixed by a pin, which passes through both the socket and its bearing. The motion of the pulley L will still continue as before; but, instead of reversing the tool, it will simply relieve it, by acting upon the screw T of the down slide, causing it to raise the tool at the end of each cut, and set it down again to the work at the return of the table.

The cutter is firmly held in its socket by setting screws *s*, and its position may be adjusted to any degree of nicety. The conditions of adjustment are these:—The flat part of the tool, or part between the cutting edges, must be exactly parallel to the surface of the work, and the cut must be equally divided between the two edges. In order to accomplish this last, the tool must be set a little out of the centre. The socket having a conical bearing, any play arising from friction may be removed by tightening the one or the other. For this purpose, a nut is placed on the socket, which acts as a collar of suspension from the bearing. The tool is set at any angle required by fixed pins, passing through circular slots in the flanges of

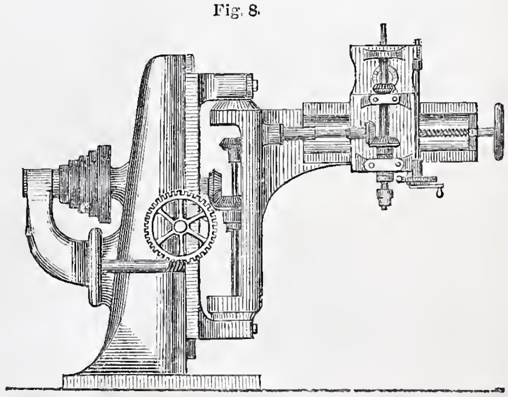
Fig. 7.



the tool-carriage, and having pinching-nuts upon their projecting ends. The whole apparatus is set to the required height above the table, by the vertical screws U U, which pass through nuts on the back of the cross-frame, and are worked simultaneously by similar pinions upon their upper ends, these pinions working into smaller pinions upon the cross-shaft V. Upon the end *x* of this shaft, a handle may be placed to work it by; or a pulley may be placed upon it, to allow of its being driven by power, when the machine is very large, and the range through which the tool is to be elevated or depressed is very considerable.

Another machine, which resembles the preceding in its general arrangement, is Whitworth's patent self-acting crank planing machine, uniform in cutting, with a quick return motion. In this machine the tool-holder is fitted with segment wheel and worm, and has a self-relieving motion. The bed-table, uprights, and cross-slide, are the same as in the foregoing. The table receives its motion from the crank by a grooved lever, in which the crank-pin slides, a connecting-rod being attached to the top end of this lever and to the table.

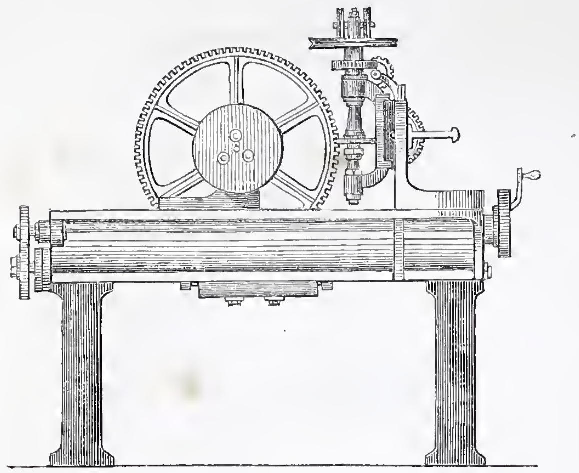
Fig. 8.



The vibration of the connecting-rod is, therefore, through a very small arc, and this enables the ordinary V-slides to be used in the bed and table.

Fig. 5 is a sketch of the patent self-acting universal shaping and planing machine. It is furnished with an adjustable crank, acting uniformly in cutting, with a quick return motion. The other parts are bed-grooved on the front

Fig. 9.



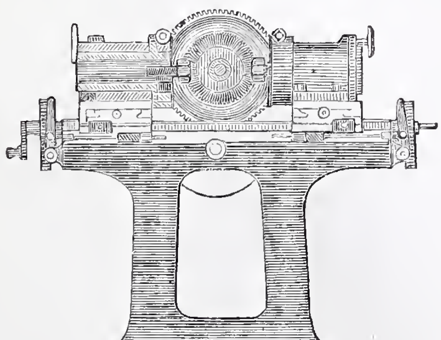
side, two tables for fixing the work, moveable vertically and longitudinally; horizontal slide, moving the full length of bed, for planing flat work; transverse slide and tool-holder, with segment wheel and worm, for internal curves; vertical slide and swivel for angular work; conical mandrel, with worm and wheel, for circular work. This machine has therefore five independent self-actions—namely, for flat, vertical, angular, and circular work, and for internal curves. It is used for shaping and planing cranks, levers, straps, cross-heads, &c., and for curves and planes in general.

Whitworth's patent self-acting slotting and shaping machine is shown in fig. 6. It is used for cutting key-ways in wheels, and for shaping work in general. It consists of independent upright framing, adjustable crank, and quick return motion; vertical slide and tool-holder; table for holding the work, fitted with two series of transverse slides—the upper series giving increased facility in chucking work to be shaped. There is also a worm-wheel for circular work, and the machine has self-acting transverse and circular motions.

Similar to the foregoing, but adapted particularly to small work, is the patent self-acting bench slotting and shaping machine.

Fig. 7 is a sketch of the self-acting vertical drilling and

Fig. 10.



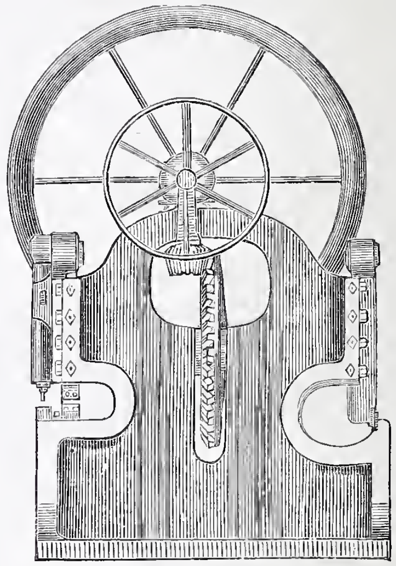
boring machine. It is double geared, with independent framing, drill spindle in tube, variable down motion and radial table, with vertical and horizontal slides. Greater facility is afforded by the radial table for chucking work than by a fixed table; and, after once fixing, any number of holes may be drilled without disturbing the work till finished.

Fig. 8 represents Whitworth's self-acting radial drilling and boring machine. It is used for drilling the end plates of tubular boilers, and for work in general. It is adapted, also, for work of a massive character, such as large cylinders, &c., which could not be conveniently lifted and placed on the table of the ordinary drilling machine. It consists of independent framing, vertical elevating slide, radial arm, moveable through an arc of 190°, slide carrying drill-spindle, with variable self-acting down motion. All holes within the range of the machine can be drilled, without removing the work till finished.

Fig. 9 is Whitworth's self-acting wheel-cutting and dividing machine for bevel, spur, and worm wheels. Its parts are—headstocks and dividing wheel, moveable horizontally for different diameters of wheels; cutter frame, with universal adjustment; self-acting traverse for cutter, self-adjusting driving pulleys, change wheel for all numbers up to 100.

Whitworth's self-acting bolt-head and nut-shaping machine is shown in fig. 10. This machine is furnished with two circular cutters, for shaping two sides at once, and two concentric chucks, for two objects to be operated upon at the same time. The chucks, which are removeable, so that other work may be shaped or squared, are respectively placed in opposite sides of

Fig. 11.



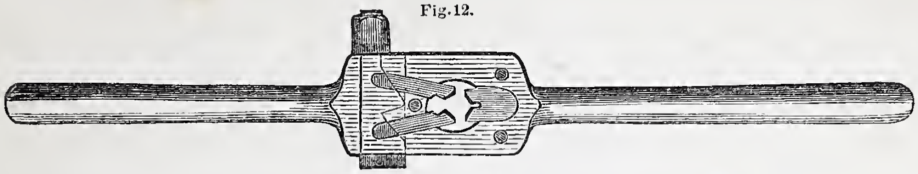
the centre of the circular cutters, by which the forces are balanced, and a much greater quantity of work is produced than if one chuck were used. There are also duplicate compound slides, with independent self-acting and self-disengaging motions to prevent injury from the cutters. These machines are applicable for shaping and squaring nuts, ends of shafts, &c.

Whitworth's punching and shearing machine for hand or power, with separate slides for the two operations, one on each side of the machine, worked by eccentrics, is shown in fig. 11. It is furnished with apparatus for raising the punch quickly without stopping the machine, and small shears for cutting off bars of any length. By this machine, punching and shearing, or bar cutting, may be carried on simultaneously without interruption.

Fig. 12 is a patent screwing apparatus, including the patent guide screw-stock and dies, working taps, master taps, for cutting up the dies, hobs for cutting screw tools, and case-hardened tap wrenches. The diameters of the working taps are made to standard gauges, and the angle of the thread is in all cases 55°, rounded off at top and bottom to two-thirds of a complete angular thread; small fractional pitches are avoided, and the principle of uniformity in pitch, form of thread, and diameter is strictly maintained. The dies of the screw-

stock are cut by a large master-tap. The inner edges of the dies being filed off to an acute angle, they cut with ease without distorting the thread; and by the direction in which they are moved their cutting power is preserved for the full depth of thread. They resemble in action and in form the chasing tool, and may in like manner be sharpened on a grindstone.

Fig. 12.



GEOLOGY.

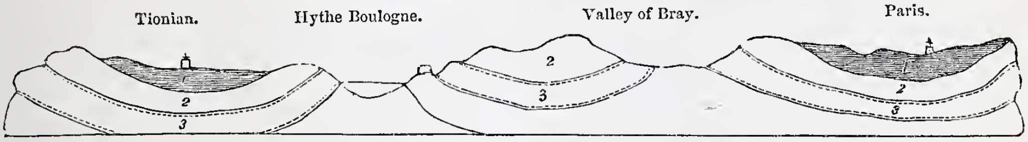
CHAPTER XIX.

THE TERTIARY SYSTEM.

We have now advanced in the history of the earth to the period when, after many revolutions upon its surface, during which various tribes of the animal and vegetable kingdoms had been repeatedly changed, a great and general convulsion took place, in which every organized being appears to have perished, and given place to creations much more varied in their character, and more elevated in the scale of organic existence. The convulsion which determined the order of Nature, that prevailed during the long period of cretaceous deposition, is considered to have given origin to the lofty ridge of the eastern Cordilleras of the continent of America. At its termination, the existing continents were found covered by inland seas and extensive lakes, in which new and elegant forms of testacea, or shell fishes, more allied to existing species, and in a few instances identical with them, began to exist. These, during the ages of the period, were gradually increased in number, and finally prevailed, while the others became extinct. On the land, now clothed with a luxuriant exogenous vegetation, all the orders of the mammalia, or suck-giving animals, man excepted, were produced, but not simultaneously—the more ancient lacustrine animals allied to the tapers giving place, on the continents of Europe, Asia, and North America, and in these islands, to the colossal mammoth or primitive elephant, the hippopotamus, the rhinoceros, the horse, the lion, and many other genera, of both carnivorous and herbivorous quadrupeds, while the huge megatherium and other gigantic Edentata roamed in the pampas of South America.

It is to Mr Lyell principally that we are indebted for a systematic investigation of these geological deposits, and in the succeeding description of them we shall follow his classification of the strata for the sake of clearness and brevity. The classification proposed by Mr Lyell is the result of extensive observations and inquiries on his part, in England, France, Italy, and the neighbouring islands. The comparative ages of the Tertiary strata are determined not so much by their position with respect to older strata, as by the numerical amount of species which they contain identical with existing species. The divisions, according to Mr Lyell's arrangement, are four in number. The first of them he has termed the Eocene; the second the Miocene; the third the Older Pliocene, and the last and fourth the Newer Pliocene.

Section showing the position and connection of the Paris Basin.



1, Eocene Formation; 2, Chalk Formation; 3. Green Sand.

The first of the above terms, Eocene, is derived from εος, *eos*, dawn and καινος, *cainos*, recent, because the fossil shells of these periods contain an extremely small proportion of living species, which may be looked upon as indicating the dawn of the recent or existing state of the testaceous fauna. The other terms, Miocene and Pliocene, are comparative: the first, meaning less recent (from μειον, *meion*, less, and καινος, *cainos*, recent); and the second, more recent, (from πλειον, *pleion*, more, and καινος, *cainos*, recent). They express the greater or less approach which the deposits of those eras, when contrasted with each other, make to the existing creation, at least so far as the mollusca are concerned. It may assist the memory of students to point out to them that the miocene formation contains a *min*or proportion, and the pliocene a comparative *plu*rality of recent species, and that the greater number always implies the more modern origin of the strata.

Eocene Formation.—This is not confined to the basins of Paris and London. The beds of Volognes, in the Province of La Manch, in France, consist of a coarse limestone resembling the calcaire grossier of the Paris basin. The limestone of La Manch is occasionally covered with a compact fresh water limestone alternating with fresh water marls. In these beds more than 300 species of fossil shells have been discovered, almost all of which are identical with the tertiary shells of the Paris basin. Several patches of strata, overlying secondary rocks, occur in the vicinity of Rennes, and are considered of the same age as the Paris deposits, the organic remains being identical. A considerable portion of the stratified rocks of Belgium belongs also to the same period.

The tertiary beds of Aix and Faveau, in Provence, also contain eocene shells; but many of them are peculiar to the formation in which they occur. The formation is of great thickness, and contains coal grit and compact limestones, such as are only to be met with in the secondary rocks of England. Some of the plants in Provence agree with those found in the Paris basin, while many of the insects discovered are considered identical with living species. These insects occur in a thinly laminated bed of grey calcareous marl. They are often in a state of perfect preservation; the impressions of their forms are delicately preserved on both the upper and lower plates of the rock in which they occur. The nervures of the wings are quite distinct, and in many instances have retained a portion of their colouring. Several of these insects are found with their wings extended as if they had made an attempt to escape by flying, or had fallen into the water while on the wing. The species of insects amount to 62, most of which are referrible to existing genera.

The basin of Paris is about 180 miles in its greatest length from the north east to the south west, and about 90 miles from east to west. The basis of the basin consists of the chalk formation, upon which the tertiary beds are superimposed. A

layer of broken chalk flints, cemented into a breccia or conglomerate by silicious sand, rests immediately on the chalk. These flints are considered by Mr Lyell as indicating the action of the sea upon re fs of chalk when a portion of that rock had emerged from the deep, and previous to the newer tertiary layers being deposited. Upon this flint breccia or, where it is awanting, upon the chalk itself, there is in many places a deposit of clay and lignite. The bed contains the remains of fresh water shells and drift timber, a circumstance which has been regarded as a proof that the Paris basin had, after the deposition of the marine chalks, become filled with fresh water; but as the lignite and clay are of very limited extent, and not confined to that portion of the series, it seems more than probable that a river charged with mud entered a bay of the sea, and drifted into it from time to time shells and wood.

The limestone known by the name calcaire grossier (coarse limestone), is the next member of the Paris basin in the ascending series. It is, as its name implies, a coarse limestone often passing into sand. Mr Lyell considers this stratum to have been derived from the degradation of a chalky country. The fossil shells found in it are exceedingly numerous. At Grignon 400 distinct species have been obtained from it. Among the shells of the Paris Tertiaries, 137 species of the Genus Cerithium occur; the species belonging to this genus of Mollusca are known to inhabit the mouths of rivers where the waters are brackish, so that their occurring in such numbers in this locality is consistent with the supposition that a river flowed into the gulf, and gave rise to the bed of lignite and clay already mentioned; but Mr Lyell thinks that there is reason to infer that the gulf was supplied with more than one river, for, while the coarse limestone occupies the northern part of the basin, another contemporaneous fresh water deposit appears at its south extremity.

The rock overlying the coarse limestone of the Paris Basin is a compact silicious limestone, which has somewhat the appearance of having been precipitated from the waters of mineral springs. Organic remains are rarely met with in this deposit; in some places, however, it does contain them. In such instances the shells are all referrible to land or fresh-water genera, whereas those in the bed beneath are always marine. In the centre of the basin the two deposits are found alternating with each other, a circumstance which tends to show, that while the bay was open to the sea, a marine limestone was formed, and at the same time the matter of another deposit of fresh water origin was introduced to the southward, or at the head of the bay, for we have every reason to believe that during the Eocene period the ocean, as now, lay to the north, and the continent, where the great lakes existed, to the south. From the latter region we may suppose a body of fresh water to have descended into the bay, charged with the carbonate of lime and silica, the water being perhaps of sufficient volume to convert the upper end of the bay into fresh water, as is the case in some of the bays of the Baltic sea.

The next members of the series are gypsum, and white and green marl. These beds alternate with the calcaire siliceux (silicious limestone) in some places, and with the upper members of the calcaire grossier in others. The gypsum, with its associated marls and limestone, is most abundant towards the centre of the basin, from which it is inferred, that while the two principal deposits were gradually in progress, the one towards the north, and the other towards the south, a river descending from the last may have brought down the sediment which went to constitute the gypsum and the marl.

The group termed the upper marine formation consists in its lower divisions of green marls. These alternate with the gypsum and marls last described. The beds above this are exclusively marine, and consist of micaceous sand, measuring 80 feet or more in thickness, above which are beds of sandstone. The summits of a great many of the hills and platforms which occur in the Paris basin, consist of the members of this marine series.

The upper marine formation is covered by the upper fresh water formation, consisting of beds of silicious limestone, as burrstone marl and marly sands.

The Eocene formations of England are confined to the districts commonly denominated the basins of London and Hampshire, the latter including the Isle of Wight. In the London basin we are not presented with the same alternation of fresh water and marine deposits as in that of Paris, nor does it afford the same interesting variety of organic remains. The lower beds consist of what is termed the plastic clay. This lower group is thus described by Philips :—

Sand of various colours, with occasional beds of lignite.

Sand and layers of clay, with or without shells.

Sand, green and ferruginous, accompanied by flint pebbles, oyster shells, &c.

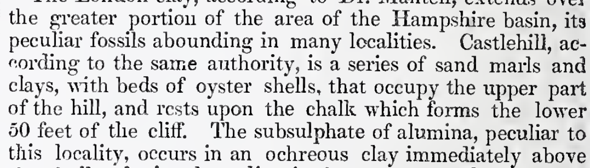
The upper group, or London clay, consists of

Bagshot sands.

London clay, of a dull-grey or blue brown, and sometimes reddish colour, containing septarian limestone, and measuring 700 feet thick. A very remarkable section of the formation is obtained at Alum bay, in the Isle of Wight, where the strata lie in a nearly vertical position. The upper group consists of, 1st, yellow and white sands; 2nd, dark clay, with green earth and septaria, rich in fossils, 250 feet thick. The under or plastic clay group, presents the following section:—1st, layer of black flint pebbles in yellow sand; 2nd, pipe-clay and sands of many colours, enclosing several beds of lignite, 543 feet thick, coloured sands of many tints, 321 feet, dark blue clay with green earth and shelly nodules, 200 feet, green sand and yellow sand, 60 feet.

The London clay, according to Dr. Mantell, extends over the greater portion of the area of the Hampshire basin, its peculiar fossils abounding in many localities. Castlehill, according to the same authority, is a series of sand marls and clays, with beds of oyster shells, that occupy the upper part of the hill, and rests upon the chalk which forms the lower 50 feet of the cliff. The subsulphate of alumina, peculiar to this locality, occurs in an ochreous clay immediately above the chalk selenite abounding in the gypsum marls. A layer of wood coal, a few inches thick, contains the impressions of plants; and the clay beds contain the remains of testacea in such abundance that some of them are merely masses of compressed shells. The oysters are consolidated into coarse stone; among these are sometimes seen sharks' teeth and fresh water shells. The remains of elephants are also mentioned by Dr. Mantell as occurring in these beds near Worthing. At Bagnor there is a sandy limestone full of shells of the same species as are met with in the calcaire grossier of the Paris basin and in the London clay, the beauty and variety of which, particularly of the nautilus, have rendered them objects of considerable attraction.

The beds in this locality, as given by Mr Webster, are, 1st, the upper fresh water deposit, consisting of yellowish white marl and limestone, employed for building, nearly 60 feet thick, and almost entirely composed of fresh water shells. Bones of the anoplotherium occur in this limestone at Binstead and Morley, near Calbourne.



1. Chalk. 2. Plastic Clay. 3. London Clay.

The organic remains of the eocene beds differ totally from those contained in any older formation. In the gypsum of the Paris basin alone, there have been found about 50 species of mammalia, all of them extinct. Nearly four-fifths of them belong to the order pachydermata, or thick skinned animals. With these are associated the remains of a few carnivorous animals, among which are a fox and gennet. The rodentia furnish a dormouse and a squirrel; and the marsupalia an opposum. Ten species of birds have been dis-

covered in these beds, the skeletons of some of which are in a very entire state; none of them are referrible to existing species. The same remark applies to the fishes, and also to the reptiles. Amongst the last are the remains of tortoises. Professor Agassiz has catalogued 72 species of fishes belonging to the London clay, 70 of which are from the Isle of Sheppey.

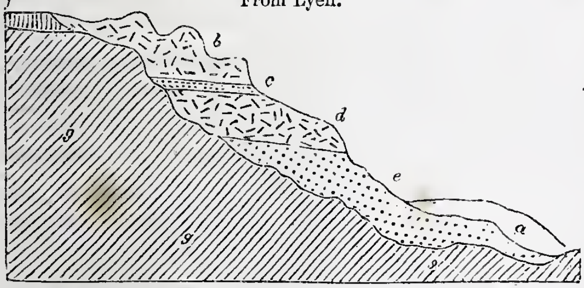
The pachydermata of the period were chiefly such as inhabited alluvial plains and marshes, and the banks of rivers and lakes. The shells from formations of this era belong to 1122 species, 38 or 40 of which are all that can be identified with the living testacea.

Miocene Formation.—Strata of the miocene period are largely developed in Touraine and the south of France, and in the Superga, near Turin. The deposits of the Loire, called the faluns, contain marine fossils; at Saucats, twelve miles south of Bordeaux, the shells are of land and fresh water genera; of 1021 species of shells obtained from the miocene strata; 176 are all that belong to living species.

In certain alluvial deposits in Auvergne, in Central France, belonging to the Miocene era, there have been discovered the remains of about 40 species of extinct mammalia, among which are found the mastodon, the hippopotamus, the rhinoceros, the mammoth or primitive elephant, the boar, horse, ox, and hyena; also, many varieties of deer, the dog, otter, beaver, hare, and water-rat. Remains of a similar kind have been found at Velay, and other places in France. In the upper Val d'Arno, in Italy, the remains of mammalia of the Eocene period are also very abundant, and are of the same species as those already noticed in the Auvergne deposits. "The skeletons," says Mr Lyell, "of the hippopotamus, are exeeedingly abundant; no less than 40 had been procured when I visited Stowell in 1828. Remains of the elephant, stag, ox, and horse, are also extremely numerous. In winter the superficial degradation of the soil is so rapid that the bones, which the year before were buried, are seen to project from the surface of the soil, and are described by the peasants as growing. In this manner the tips of the horns of stags, or the tusks of the hippopotamus, often appear on the surface, and thus lead to the discovery of an entire head or skeleton."

The Miocene sedimentary deposits of Hungary, Transylvania, Styria, and Auvergne, are often interstratified with volcanic rocks, which show that those districts were at that period disturbed by volcanic eruptions.

Portion of the Miocene Alluviums of Mount Perrier, in Auvergne. From Lyell.



a Newer alluvium.
b Second Trachyte Breccia.
c Second Miocene Alluvium, with bones.
d First Trachyte Breccia.
e First Miocene Alluvium, with bones.
f Compact basalt.
g Eocene limestone strata.

Older Pliocene Formation.—The deposits of this period occur in the subapennines of Italy at the base of the maritime alps, at Genoa, Savona, Nice, the eastern extremity of the Pyrenees, and in Norfolk and Suffolk in England. Beds occurring in such distant localities present different lithological characters; their comparative age can therefore only be determined by superposition, or by the organic remains which they contain.

The subapennine beds consist chiefly of marl in thin laminæ, sand, and conglomerate. In some hills near Parma this marl is nearly 2000 feet thick, and throughout contains shells, many of them being such as inhabit a deep sea. These shells often occur in layers in such a manner as to indicate slow and gradual accumulation. The yellow sand and conglomerate of the subapennines in most places form a border near the junction of the tertiary and secondary rocks. The conglomerate lies beneath the sand in one place for eleven miles. Blue clay, yellow sand, and marl, seem generally to characterise the formation in the other continental localities. Fossil shells everywhere abound.

There is a rock in the counties of Norfolk and Suffolk seen in some places resting on the London clay, and in others upon the chalk, called the Crag. It consists of two distinct masses, the upper or red crag, and the lower or coralline

crag. The nature of the stratification is such as to indicate that it is the remaining portion of an old shifting sand-bank, the oblique layers sometimes slanting in all directions in different parts of the same quarry. The upper deposits consist chiefly of deep red or ochreous coloured sands and shells. It is sometimes used as a building stone in which entire shells, echini, and corals are imbedded. The coralline crag varies in thickness from 15 to more than 20 feet; the red crag is often much thicker—about 450 species of shells have been obtained from these deposits, almost all of which differ from existing species. There are scarcely any corals in the red, but they abound in the coralline crag.

Newer Pliocene Formation.—Mr. Lyell has applied this term to those numerous deposits of sand, gravel, &c. met with in almost every part of the world which contain shells, chiefly of recent species. Such formations occur on the Rhine, from Cologne to the frontiers of Switzerland, measuring from 200 to 300 feet in thickness, and rising from the height of from 300 to 1200 feet above the level of the sea. In this and similar deposits, bones of the mammoth, of extinct elephants, together with those of the horse and other quadrupeds, have been met with, but no trace whatever of man or of his works. Indeed, as Mr Lyell justly observes, "no marine strata of the recent period have yet been brought to light in England, which rise to such a height above the level of the sea as the highest tides may not have have reached. Ships have been found buried in the former channels of the Rother in Sussex, of the Mersey in Kent, and the Thames near London. Canoes and stone hatchets have been dug up in almost all parts of the kingdom, in peat and shell marl, but there is no evidence, as in Sweden, Italy, Peru, Chili, and other parts of the world, of the bed of the sea having been lifted up bodily in modern times, so that the recent formations have become land. There are, however, newer pliocene formations in various parts of Great Britain and Ireland of marine origin, consisting of sand and clay, usually of small thickness; as, for example, Cornwall, and near the borders of the great estuaries of the Clyde and Forth in Scotland, and in that of the Shannon in Ireland. These are usually found near the coast, but in some instances they penetrate inland to a distance of 60 miles from the sea, as at Bridgenorth, in Shropshire. They rise also occasionally to great heights, as at Preston, in Lancashire, where they are 350 feet above the level of the sea: and what is still more remarkable, on a mountain called Noel Tryfane, in Wales, near the Menai straits, they attain an elevation of about 1400 thousand feet above the level of the sea. In all these places they contain shells indisputably of the same species as those which now people the British seas; and although perhaps on accurate examination, some slight intermixture of extinct testacea will appear, yet the geologist will always refer them to the most modern tertiary era."

The beds referred to in the foregoing extract as occurring on the shores of the Forth and Clyde, are beds of sand-clay and gravel, the lower of which have been deposited while the motion of the sea extended over lands now elevated from 50 to 70 feet above its present level. Such beds are cut through by the line of railway between Glasgow and Paisley, and by that between Port-Glasgow and Greenock, at elevations of from 50 to 60 feet above high-water mark. The clays are laminated, and contain many shells, which are still found on the coast, but some of them have entirely disappeared from the British seas, and others are of species hitherto unknown. The whelk, oyster, and razor shell, are common. From these and similar beds, Mr Smith, of Jordanhill, has collected about 160 species of marine shells. Two miles from the Glasgow railway station the marine clays are overlaid by a similar deposit, but the shells contained in it belong to the fresh water genus limnea. These shells are very plentiful in this bed. The beds overlying this deposit are layers of river sand and gravel. Those at Glasgow rise to about 40 feet above the bed of the present river, and extend from the centre of the city to the Paisley canal, where the laminated clays are used in the manufacture of brick.

The lowest of these beds repose on a deep deposit of unstratified dark coloured sandy clay, in which gravel and blocks of stone of various sizes are irregularly dispersed in immense quantities. The Boulder Till forms the most of the summits of this and the other districts of the lowlands of Scotland. It is also found filling what have formerly been ravines, to the depth of from 40 to 70 feet, or more. The clays are mixed up, not only with the fragments of the subjacent rocks, but the great majority is frequently composed of blocks of granite, gneiss, mica slate, and other primitive blocks, mixed with those of porphyry, basalt, and traps of almost every variety. These boulders must have come from great distances, as granite does not occur nearer than the remote districts of Perthshire, and many of the trap rocks are quite unknown in the intermediate distances.

These boulders are almost all smoothed and scratched at the surface with parallel furrows or grooves. The granites are more rounded than the others.

Such clays and gravels, with transported boulders, are not only strewed over the solid strata of this, but of almost every other country in Europe, in Asia, and in both North and South America, at low as well as elevated levels. In Scotland we find them at least 600 or 700 feet above that of the present sea. Some of those which occur in England and Scotland are conjectured to have travelled as far as from Norway.

It is to be remarked, that though the boulders indicate transport, the clays in which they are imbedded generally partake of the colour of the prevailing shales of the formation they overlie. There can be no doubt that the clays in such instances are chiefly composed of the debris of the subjacent strata. In extensive tracks covered with trap rocks, these clays rarely or never occur. This tends to show that the hill was not transported in one mass to its present site from any considerable distance, however far the boulders contained in it may have come.

Professor Agassiz has attributed the transport of the till, as the formation is now generally denominated, to the agency of glaciers, bearing, as it does, a strong resemblance in its general character to the *moraines* deposited by these masses of ice upon the sides of alpine regions, the stones in these moraines being smoothed, rounded, and longitudinally scratched, as in the boulder till.

That the primitive boulders assumed their present forms and peculiar appearances under the influence of glacial action, is not improbable; but that they were drifted in one mass with the clays from those far off districts, from which the boulders must have come, is not so probable. It seems more likely, we should imagine, that they were carried by icebergs from the localities to which they originally belong, in the same manner as similar masses are carried off from the shores of arctic countries at the present day, and deposited at the bottom of the sea hundreds of miles from their native site. To account for their being mixed up with the debris of the rocks upon which they now repose, we must suppose that during the last tertiary period a very violent disturbance took place, and the waves of the ocean acting, in consequence, with immense fury on the irregular surface of the bottom of the ocean, great masses were denuded and became mixed up with the boulders, previously, or at that time, borne to the locality by the agency of the ocean. The immense disturbance prevented the matter assuming a stratified character, and hence the till indicates nothing so much as chaotic confusion.

This period of disturbance appears to have been that of the last great convulsion of the globe, by which the then existing tribes of land animals became extinct. The buried remains of elephants, rhinoceroses, tapirs, hippopotami, lions, tigers, &c., indicate a change in the temperature of the northern hemisphere at least; and the evidence of glacial action in regions where nothing of the kind now exists, attests the same fact.

Whatever may have been the causes to which we are to attribute the existence of the Boulder Till, evidence exists that it took place while animals now found only in tropical regions existed in this and the other countries of Europe, and in all probability before the creation of the human race. That it belongs to a period more remote than that ascribed to the Noachian deluge, is evident from the effects which can be traced as having been produced by the action of the present ocean, at much lower limits than those at which the till occurs: effects of abrasion and deposition altogether incompatible with the known data of historical record and the character of existing agencies, on the supposition of its occurrence only taking place within the last four thousand years.

THE SCIENCE OF PHRENOLOGY.

CHAPTER VI.

ORDER I.—FEELINGS.

GENUS I.—INFERIOR PROPENSITIES.—(*Continued.*)

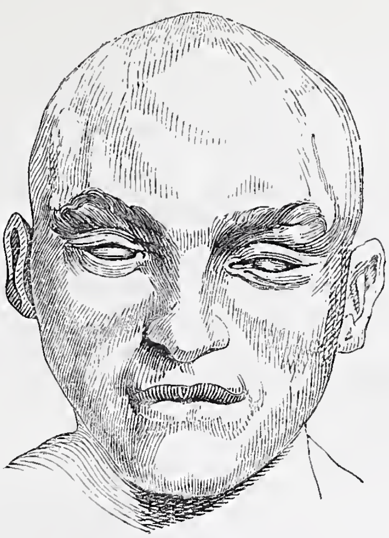
6. DESTRUCTIVENESS.—(*Continued*).—The illustrations of this faculty are unhappily too numerous. Perhaps the most extraordinary, both from the nature of the crime and the extreme artfulness with which it was accomplished, and the sensation it excited, is contained in the narrative of the murder of Lord Wm. Russell by Courvoisier. We shall abridge the particulars from the public papers of the time.

Lord Wm. Russell was found in his bed, on the morning of May 6, 1840, murdered; there was a deep gash in his throat, and the windpipe and principal blood-vessels were divided. His cash-box, desk, and dressing-case, were found broken open; his watch, rings, money, &c. were missing; but various articles of value were lying about untouched in the bedroom.

He had a Swiss valet named Courvoisier. Upon him, suspicion fell almost from the first. Besides the valet, there were two others, a housemaid and a cook, the two females sleeping in one room together, and the valet in a room adjoining. It appears that the housemaid generally rose first, and as she passed to her duties, knocked at the door of the valet. On descending, she saw some articles of value lying in the hall near the front door, packed up as if for the purpose of being carried away, while the house seemed to be in confusion. She immediately returned and acquainted her fellow servants. She and Courvoisier entered the sleeping room of Lord William, and discovered the room as we have described, and the body of his Lordship. Courvoisier was much agitated; he exclaimed, "My God, what shall I do, they will think it is I. I shall never get a place again, &c."

The police were soon on the spot, and proceeded to examine the house. There were some marks on the area door and doorpost, which Courvoisier pointed out and said, "There's where they came in." The plate drawer had been broken open, and

a chisel found in Courvoisier's box corresponded with the marks on the drawer. The servants were kept separate under the eye of the police, who commenced a strict search over the whole house. Some portions of the missing property were found behind skirting boards, water-pipes, under the floor of Courvoisier's pantry, and under the hearth-stone of the kitchen fireplace a small locket was discovered among the rubbish. Courvoisier was arrested on suspicion of being the murderer, but protested his innocence, and no weapon could be found which led to any traces of the murder.



The watch and other articles were found in Courvoisier's pantry, but there was no absolute proof that he had placed them there. Large rewards were offered for the missing plate, which it was suspected must have been removed before the night of the murder, but no tidings of it could be obtained. On the second day of the trial, however, the landlady of a French hotel in Leicester Place, came forward with the missing plate, which had been left at her house in a sealed parcel, some days before the murder, by a man who had formerly served as a waiter in her hotel, and whom she only knew by the name of John. She did not know where he was living at that time, as he had only told her he was in a situation, and requested her to take care of the parcel for him, till he called for it. She did not know what it contai ed, and had no suspicions till that morning, when she opened the parcel in the presence of witnesses, and finding the nature of its contents, immediately came forward to give her evidence. She was taken to the prison, and a number of prisoners being shown to her, amongst whom was Courvoisier, she immediately

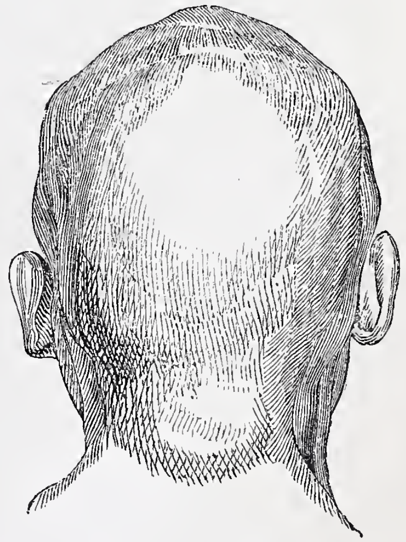
pointed him out as the person who had left the parcel with her. Upon this evidence he was convicted, and it subsequently appeared that he was confounded at the discovery of the plate, and confessed the crime to his counsel.

He made two or three confessions, each differing in material points from the other. We subjoin the last, as being probably the most correct:—

"Newgate Prison, July 4.

"After all the false statements which have been published in the newspapers, I feel constrained to tell you again all things as I related them to you when my uncle was here. If there are any contradictions, it is because I did not rightly understand the persons who questioned me, or because my answers were not well understood. It is true that I have not told the truth to Mr. Flower, but I have stated the reason why I did not. The public think now I am a liar, and they will not believe me when I say the truth. Therefore, I pray you will correct all misunderstanding on the subject; and I think it is good that I should relate again all that has passed, and how it passed. The evil dispositions of my heart began by a strong hatred of my situation, and by the wish for another situation. My next idea was, that I could live at the expense of others. Then I thought, that if I were to rob my master of £30 or £40, it would be so much gained; and I had afterwards the idea, that by killing my master, the robbery would be better concealed, and that I should have done with him all at once, and be ready for my journey. I took the plate out of the house on Saturday or Sunday evening. I was waiting for a favourable opportunity of accomplishing my design.

"On Monday evening, the 4th of May, I had an evil thought of putting my hand to work; but after I had forced the door, a remnant of conscience told me I was doing wrong. I stopped about ten minutes without knowing what to do. I vanquished the temptation of the devil, and went to bed, after having put again the door in order. Oh! if I had but deter



mined so on Tuesday night, how happy I should be! I ought at least to have prayed to God, and thanked him for having preserved me during that temptation. But I went to bed like a dog, without thinking even that God had seen me. Tuesday evening, the 5th of May, I had some altercation with my master, but it was not worth the while to speak of it. When he was in bed I went down to the kitchen, where I remained

about an hour and a half. During that time I placed all the things in the state in which they were in the morning in the passage, &c. I went up stairs, and going by the dining-room, I entered it and took a knife. I believe it was a great knife. I went up to Lord W. Russell's bed-room. When I opened the door I heard him asleep, and stopped for a while, thinking of what I was about to do, but the evil disposition of my heart did not allow me to repent. I turned up my coat and shirt sleeve, and came near to the bed on the side of the window Then I heard a cry of my conscience telling me, 'thou art doing wrong;' but I hardened myself against this voice, and threw myself on my victim, and murdered him with the knife I was holding in my right hand. I wiped my hand and the knife with a towel, which I placed on the face of Lord William. I then took his keys and opened the box in which he kept his bank-notes. The double Napoleons which I found were more than I expected. I put them in a purse with the rings, &c. I took also the watch, and placed them altogether in a basket till the morning. I placed a pair of shirt buttons, a pair of spectacles, and ten sovereigns, under the staircase carpet which goes from the drawing-room to Lord William's bed-room. I went to bed.

"On Wednesday, when the police had searched a little everywhere, I perceived that they watched me more attentively than the other servants, and that they began to examine very carefully. I crept in the bottom of the scullery, and seized the parcel I had put there during the night, and put it in my pocket. As soon as I was in my pantry, I placed the purse where it was found. One of the police came then to me and told me I must go with him, so that I had no time to conceal the watch. I was kept in the dining-room the whole day, excepting the time my room was searched, and I could not get rid of the watch.

"On Thursday, the 7th May, when I went to bed I took what I had placed under the staircase carpet. Friday morning, I wrapped two sovereigns in some paper, and concealed them in my stockings. I went down to the pantry. Nobody being there, I placed the watch and the ring where they were found. The policemen came then into the pantry to shave and wash themselves. I went to the kitchen and burned the watch ribbon. I did not know what I was to do with the seals and two watch keys. I could not get rid of them for the present, and was replaced in the dining-room. All the morning I entertained the hope that the things I had hidden would not be discovered. I broke one of the watch keys in three or four pieces, and then threw them in the fireplace; I broke also the top and the bottom of the other. After they had found the purse, &c., they brought me down into the pantry, where I stayed for some time. One of the inspectors went then into the scullery, in which I entered also, thinking of a place where I could conceal the two seals and the watch key, the two extremities of which I had broken. The inspector stooping to look under the sink, I placed the great seal where it was found, and threw the broken key among some old rubbish at the bottom of the scullery. I then came near the door. After that, two inspectors and two masons being there, when I saw them busily engaged, I let the small seal fall to the ground, and put my foot upon it in order to bend it. I stooped as if looking under the boiler, took up the seal with the left hand, and rose up. I leaned my hand against the wall for a time, waiting for the moment when those who watched me should turn away their heads, and succeeded in placing the seal behind the pipe where it was found. The inspectors went out thence to the kitchen, excepting one, who remained in the pantry with me for about an hour. During that time, I let fall the small locket of Lord William, and two sovereigns. They took me then to my room, where I was searched for the first time. I had two policemen with me. They made me draw off my boots, but not my stockings. I went not to bed on Friday night, nor on Saturday. On Saturday night I went to bed for five minutes, but I did not draw off my stockings. They made me rise up, and led me into prison. When I was in Tothillfields prison, they searched me very carefully. I feigned to be very cold and shivering, as a person who has the trembling fever, thinking they would let me keep my stockings on. But they told me to take them off. As I had three stockings, two on the right leg, I first took off the stocking which was alone, and then one of the others. When they were feeling if there was any pin or needle, I placed my hand under my heel, and concealed the ten sovereigns in a paper under the thumb of my hand. The following morning they made me take a bath, when I had a good opportunity of hiding them on my person, where they remained till the morning of the day I came to Newgate. I thought that perhaps I should be examined more closely, and that, should that money be found on me, it would be sufficient to condemn me to death. But other evidence was found, and this was not wanted. I placed one behind the post of a bench in the cell of Bow Street, the last time I appeared before the magistrates, three on the top of the door, one on the window, as I believe, and four or five in the pit of the water-closet.

"This is, Rev. Sir, to the best of my recollection, a faithful account of what has passed since the time I conceived the dreadful idea of robbing and murdering my master to the day I came to Newgate. I wish to express to you my deep gratitude for the spiritual instruction you have given me, and your interest in the salvation of my soul.

"I am, my dear sir, your humble and thankful servant,

"F. B. Courvoisier."

The Editor of the London *Examiner* thus comments upon the criminal's confessions:—"Two statements, said to have been made by this miscreant on the Friday and Sunday before his execution, have been published under the sanction of the chaplain of Newgate. They were written, according to the newspaper accounts, in French by Courvoisier, for the Rev. J. Carver; and of all the disgusting, fictitious, and canting effusions that have ever issued from the cells of murderers, these are, without exception, the most offensive. The man who murdered his master for the sake of his property, and who afterwards adopted the most ingenious mode, perhaps, ever contrived of concealing his horrible crime, is made to say, in one of these effusions, that he is not the guilty person, but Satan alone is to blame; and in the other, that Christ is his friend, and promised him repentance, and admission into the kingdom of God. We can hardly conceive it possible that the chaplain of Newgate, or the minister of the French protestant church, would have encouraged the miserable wretch to outrage religion and virtue by such indecent statements; but they have incurred great responsibility, by allowing them to go forth to the world with the sanction of their names. We give two extracts from this libellous attack on what Burns so charitably calls the 'puir deil.' The first is his formal classification of his rupture of the ten commandments:—'I have taken Satan as my God; that is contrary to the first commandment. 2. I have adored the riches and pleasures of this world, and have loved them more than God. 3. I have often taken the name of the Lord in vain. 4. I have made the day of the Lord my day of pleasure and amusement. 5. I have disobeyed my parents. 6. I have murdered. 7. I have been in company with notorious debauchees. 8. I have robbed. 9. I have spoken ill of my neighbour. 10. I have desired the wealth of others.' The second descends from the celestial flights to some ordinary life statements connected with the atrocious crime of this unmitigated ruffian. 'During the first part of the time I was with Lord William Russell, I was tolerably comfortable until we went to Richmond, when Lord William always appeared dissatisfied, especially towards the latter part of the time. I fancied that I should not be able to remain with him; and having heard the other servants speak of different scenes, (towns, villages, and country houses,) I began to desire an employment which would enable me to travel through England. I afterwards formed an idea that I should be able to travel on foot from city to city, for six or seven months. I then intended to endeavour to procure a place, or return to Switzerland. I thought I should be able to make my friends believe that I was in place during these six months. This was the beginning of my misfortunes, for I soon commenced to harbour still worse designs. I thought that I could go to a town, take a lodging, and after remaining

five or six days, I would depart without payment. I thought that £10 or £12 would suffice for this excursion, and began to seek an opportunity for departure. But this was not enough; I began to premeditate the seizure of what this venerable victim had with him in gold, in bank-notes, and his watch; but this did not satisfy me. Satan, who knew that he had my heart in his power, began to persuade me that it was not enough only to rob my master, and that, if suspicion rested upon me, the world would be ready enough to believe it; and as, during the time I was at Camden Hill, I read a book, containing the history of thieves and murderers, being under the dominion of Satan, I read it with pleasure. I did not think it would be a great sin to place myself among them. On the contrary, I admired their skill and their valour. I was particularly struck with the history of a young man who was born of very respectable parents, and who had spent his property in gaming and debauchery, and afterwards went from place to place stealing all he could. I admired his cunning, instead of feeling horrified at it; and now I reap but too well the fruit of those papers and books, which I had too long suffered to supplant devotional works; and this book—yes, this book—was read by me with more attention than the Holy Bible.'"

It would appear, that, notwithstanding his apparent penitence, he had hit upon a plan of self-destruction. We return again to the newspaper account:—

"It was ascertained by Mr. Cope, the governor of Newgate, on the preceding night of his execution, that Courvoisier had devised a plan for anticipating the hangman's business. Indeed, the governor suspected, from the moment of conviction, that the murderer would exercise all his ingenuity to dispatch himself, and two of the most active and vigilant turnkeys were appointed to remain with him night and day. The suspicion, Courvoisier acknowledged shortly before his execution, was well founded. He had been, he said, constantly occupied in meditating upon finishing his career by murdering himself, notwithstanding the extraordinary readiness he had shown to engage in prayer, and to read and quote the scriptures with the Ordinary and Sheriff Wheelton, who, to do them justice, were constantly at his elbow, endeavouring to sound the depth of his penitential feelings. But if Mr. Cope was cautious at the early period of the confinement of his prisoner, he exercised double caution, the night immediately preceding the execution. At half-past ten o'clock on Sunday night, the governor went into Courvoisier's room, and told him that it was time for him to strip and go to bed. There was an evident repugnance on the part of the prisoner to take the hint. He hesitated very much; but finding that the governor was resolved to be obeyed, he did as required. By the direction of Mr. Cope, also, the mattress on which the prisoner had lain since he had been in Newgate, was removed, and another was substituted. The governor himself then searched the clothes of Courvoisier, and found rolled up, in a corner of his coat pocket, a strip of dark cloth, which, notwithstanding the rigorous search made before and after the condemnation, never met the eye of any of those appointed to watch his movements. When the governor asked Courvoisier where he got the strip of cloth, and what he intended to do with it, he replied, with one of those numerous shakes of the head with which he was in the habit of confessing his crimes, that he meant, if the governor had not prevented him by suspecting his sincerity, to make a corpse of himself before the hour of the execution arrived; and that he had gone into the water-closet, and tore up the slip of cloth along the inside seam of his trowsers, and that he intended to tie it so tight round his arm, as to develop as much as possible the large veins, which in the darkness of the night he proposed to open, so that in the morning he should be found fit for the grave. He submitted that, to a person in his circumstances, with an ignominious death before his eyes, the alternative of a silent departure was the most eligible choice; and notwithstanding all the religious exhortations, public and private, which he had received, he had made up his mind on the matter. 'But how could you have bled yourself?' said Mr. Cope. 'Your regulations completely put all my hopes to flight, said Courvoisier, for the mattress which you sent away had concealed in it a small piece of wood, which I had sharpened in such a manner that I could easily have opened my arm with it. I have been long looking about for a pin, but not finding one, I took up a bit of stick, with which you light your fires, and managed, after giving it a point, to put it in my mattress. 'So then,' said Mr. Cope, 'you have been all along contemplating self-destruction?' 'Not a doubt of it, sir; I would have ended myself if I could.'

"No piece of wood was found in the mattress; in the hurry and confusion of removal it might have been lost, or the prisoner might have indulged himself with another lie before his exit.

"Courvoisier, whose firmness never deserted him, and astonished even those the most used to such scenes, had retired to rest last night at eleven o'clock, and slept soundly for an hour, when he awoke, and inquired of Locke and Sargent, the turnkeys in attendance on him, the hour of the night. On being informed that it was only midnight, he desired to be called at four o'clock, as he had some letters to write.

"He fell asleep a few minutes after he had lain down, but woke up at twelve, and asked Locke what o'clock it was; the turnkey told him it was just twelve, upon which he again lay down and went to sleep. His conduct never altered throughout, and during his waking hours he never gave way to violent grief, nor did he ever manifest any remarkable degree of excitement or agitation at the approach of death. His sleep was generally calm, and tolerably sound; but he would sometimes groan, and gnash his teeth. One of the turnkeys, comparing the prisoner with other condemned criminals who had come under his notice, described him 'as a pleasant man enough to be with.'

"The murderer slept well until four o'clock. He then rose, and at six o'clock, Mr. Wheelton the sheriff, and Mr. Carver the ordinary, repaired to the room, and were joined by him apparently with fervour, in prayer. Mr. Baup, a Swiss clergyman, who has been frequently with the prisoner since his confinement, soon afterwards arrived. The latter reverend gentleman, it appears, was impressed with the idea, before the trial, that Courvoisier was guilty of the murder, but altered his opinion in consequence of the ingenious acting of the murderer, who has since declared that, from his early youth, he had an unconquerable propensity to lying.

"Certainly, from all appearances, it is but reasonable to infer, that Courvoisier was one of the most desperate and cold-blooded cut-throats that ever appeared upon the platform of the Old Bailey.

"At half-past six o'clock, Mr. Newman, the head turnkey of Newgate, was ordered to take the sacramental bread and wine into the prisoner's cell: after the conclusion of this religious rite, Calcraft, the executioner, entered with a black bag, containing a rope, with which his arms were pinioned. The prisoner clasped his hands together to undergo the operation, and in this position the rope was put round his arms and wrists. The reverend ordinary continued to pray with him for some time, and put several questions to him as to whether he was fully penitent for the crime he had committed, and whether he believed in the atonement of a Saviour;—to which, in barely audible whispers, he replied in the affirmative, accompanied by an expression of countenance which but too plainly showed the deep anguish of his soul. As he spoke, he wrung his hands, and, as far as the ropes with which he was bound would allow, raised them upwards. His form was much attenuated, and his eye expressive of the deepest mental suffering; death was as visibly stamped on his features, as it could have been on the death-bed. The prisoner's cell was the one occupied by Greenacre. A few minutes after eight o'clock he was conducted to the scaffold, and as they proceeded the reverend ordinary read the burial service.

"The prisoner walked up the steps to the scaffold without any apparent agitation, and as soon as he appeared the assembled multitude commenced groaning, which they continued some time; but it did not appear to produce any effect upon him, and he stood firm and unmoved while the preparations were making. Everything being adjusted, all eyes were fixed upon the wretched criminal. The reverend ordinary stood with him about two minutes, and then left the scaffold;

immediately the bolt was withdrawn, and a few seconds ended the life of the criminal, who died without a struggle.

"At the request of the sheriff, who asked him to write something on an envelope a few minutes before he was led out to execution, he wrote, with as steady a hand as any in the room possessed—

"FRANCOIS BENJAMIN COURVOISIER,
the 6th day of July, 1840, the day of my execution."

Such was the account given in the newspapers; and shortly after the execution we were furnished by Mr. Donovan, of the Phrenological Institution, London, with a plaster-cast of his head. It is exactly of the criminal type. The head was large and powerfully organized, being $23\frac{1}{2}$ inches in circumference. There was an immense amount of cerebral matter at the sides and back part of the head. The forehead is very narrow, and the upper parts retreating, while the lateral portions of the crown slope gently down, rendering it keel-shaped.

If we signify mean development by 14, rather large by 16, large by 18, and very large by 20; small being expressed by 8, rather small by 10, and moderate by 12, the following will be the development:—

Amativeness,	20	Imitation,	12
Philoprogenitiveness,	14	Wit,	10
Inhabitiveness,	14	Individuality,	20
Adhesiveness,	14	Form,	18
Combativeness,	20	Size,	16
Destructiveness,	20	Weight,	16
Secretiveness,	20	Colouring,	18
Acquisitiveness,	20	Locality,	18
Constructiveness,	18	Number,	14
Self-esteem,	20	Order,	18
Love of approbation	20	Eventuality,	14
Cautiousness,	20	Time,	14
Benevolence,	10	Tune,	14
Conscientiousness,	12	Language,	16
Hope,	12	Comparison,	14
Marvellousness,	12	Causality,	14
Ideality,	12		

FARRIERY.

CHAPTER I.

INTRODUCTION.

THE term Farriery has long been used to signify the medical and surgical treatment of the horse, embracing also "shoeing," to which its signification was formerly restricted. More recently the term has been extended to the cure of the maladies of all domestic animals.

Although the name "ferrier" is known to be of great antiquity, and was in general use among the Latins, yet we have no definite account whether by these enlightened people it was studied as an art or merely practised by blacksmiths and untutored persons. It is known, however, that the Italians and French were the first, in more modern times, who turned their attention to the study of diseases which afflict domestic animals, and upwards of two centuries have elapsed since they established professorships for teaching the art of farriery as a distinct branch of medical and surgical science.

The person to whose tender mercies the cure of the various complaints incidental to the horse was committed, was the parish blacksmith, who was denominated *ferrer* or *ferrier*, terms derived from the Latin word *ferrum*, iron, and hence the trade or practice—ferriery; a word which, in this country, has, in the course of time, been changed into farrier, and is now in universal use. It was not in Britain alone that the blacksmith was the farrier, but almost universally throughout Europe. Indeed, in remote country situations, that personage still holds this very responsible office. In towns, however, and the more important villages and thickly-peopled localities, regularly educated persons now practise the art of farriery. Indeed, it has now become a fixed science, and there are many distinguished professors who lecture on the subject in various large towns throughout Great Britain. Moreover, the training of pupils for this branch of medical science, requires nearly as much time and study as are devoted to the pursuit of human anatomy and physiology, to fit the student for the practice, treatment, and cure of all those diseases to which humanity is liable. Diplomas are granted by such professors to young men who have undergone the regular course of study, and who are found, upon a rigid examination, to be fully competent for this important office. The veterinary art is now entitled to claim a kindred position with human medicine, anatomy, and physiology, as these sciences are, in fact, their common parent.

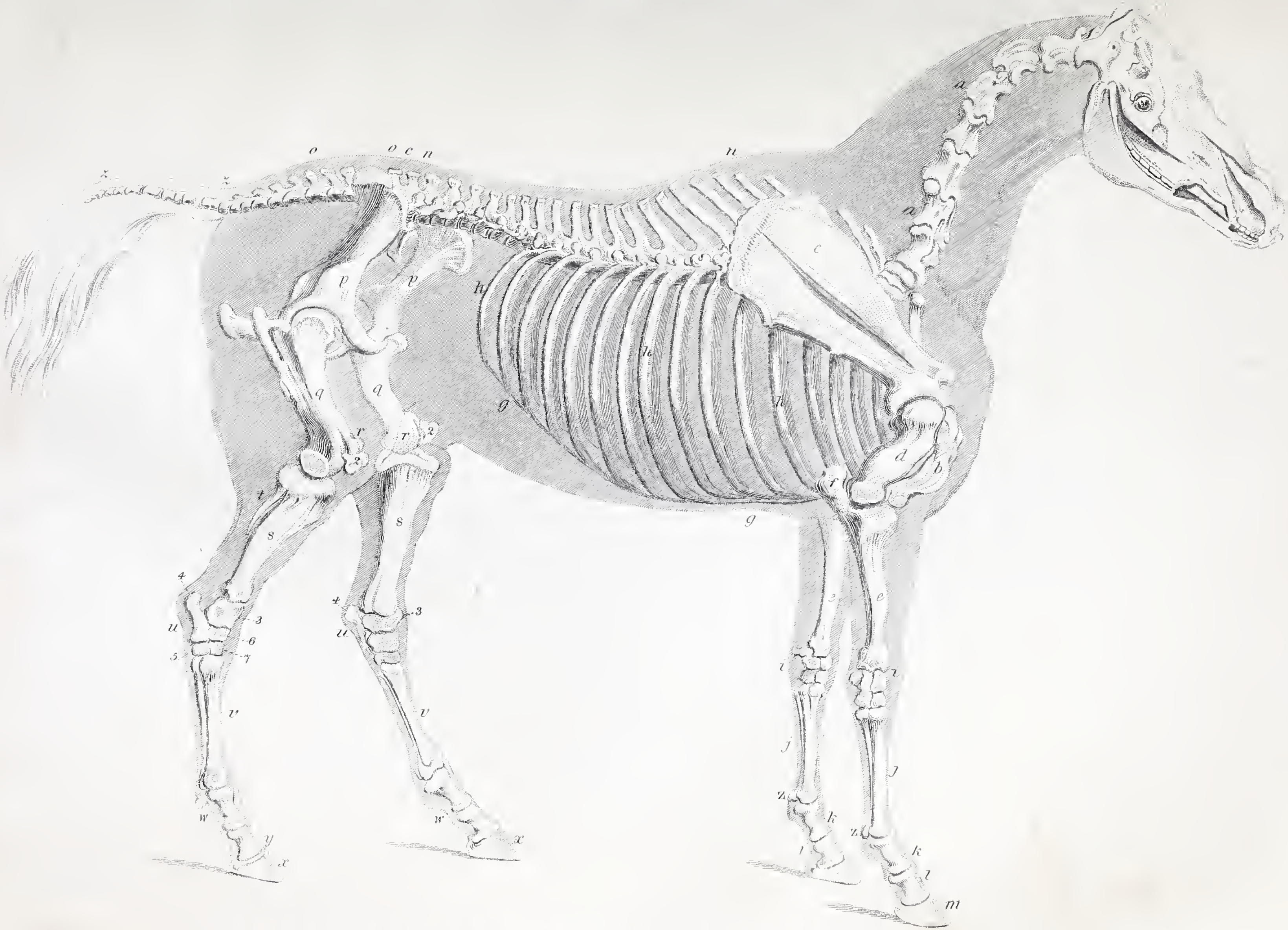
It may be well conceived that the horse is afflicted with nearly as many diseases, some of them as complicated in their nature, as those to which man himself is subject. How then can it be expected that a blacksmith, who earns his livelihood by the sweat of his brow, and who has undergone no course of anatomical or medical study, can be competent to such a task? Indeed, we ourselves have found such persons entirely mistaking the malady which they were treating, and dispensing medicine to the poor animals which aggravated the complaint instead of alleviating or curing it. Nevertheless, there are many sensible men exercising this calling, who, from long experience, though not possessed of a regular professional education, are competent to cure the more common diseases to which horses and cattle are liable. By practice, gentlemen, grooms, and coachmen, often acquire considerable knowledge of animal complaints of the more ordinary kinds, and for their especial use the following treatise is intended; in complicated diseases we by no means intend to supersede regular veterinary surgeons, but, on the contrary, recommend immediate application to be made to them in all cases where there is the slightest difficulty.

We have said that anatomy and physiology are indispensable studies to the veterinary art. It has been justly remarked, that the surgeon has lived to the day to be convinced that no so sure road to reputation and distinction lies open to him as through the dissecting-room, and this "is equally applicable to the veterinary surgeon." A professor of medicine, with a mind unfurnished with anatomy and physiology, is precisely in the situation of a mechanic who undertakes to repair a deranged or broken machine without any acquaintance whatever with its mechanism or operations. Both such persons are empirics, and worse than empirics—impostors in their professions; either of them may perchance do good, but there is ever much to be apprehended that they may be working some irreparable mischief. We hear of "wonderful cures" being performed by persons having no pretensions whatever—indeed, possessing none—to medical science; and in this hit-or-miss manner of proceeding, it cannot be denied that some valuable discoveries have been made; but were we to set against these discoveries, brilliant as some of them may have turned out to be, a full catalogue of the failures and evil consequences which have accompanied such experiments, we apprehend the discoverers themselves would blush at the dark complexion of the result.

It needs no reasoning to convince every reflecting mind, that fundamental knowledge is necessary in every department of science; does it not, therefore, appear strange, at this time of day, to see men of education committing their horses, in health as well as disease, entirely to the charge of their grooms, whose only faith is too frequently pinned to the sleeve of a blacksmith in time of need, rather than (for a petty saving) consult the veterinary surgeon, who alone is qualified to comprehend the nature and cause of disease; and whose superiority of knowledge, by education and practice, equally qualifies him to comprehend the nature and course of disease, and to treat it successfully?

Having said thus much as to the absolute necessity of the study of anatomy, it will be our care to lay before the reader a pretty full description of the different parts of the horse, internally as well as externally; and when an idea of the situation, form, connection, and structure of most parts of the animal body, have be acquired, so as to fit the reader for dipping deeper into the study, we shall then treat of the diseases incidental to horses and other animals, with their mode of cure, as far as is known at the present time. But the student must not be satisfied with anatomy alone—he must make himself acquainted with the laws of physiology, which teach us the action or use of the various animal members. Comparative anatomy, likewise, will

FARRIERY.



BONES OF THE SKELETON OF A HORSE.

ELEMENTARY FOSSIL CONCHOLOGY.

ELEMENTARY FOSSIL CONCHOLOGY.

ELEMENTARY FOSSIL CONCHOLOGY.

PLATE

form a valuable addition to the practice of the veterinary art; for although a general similarity of structure prevails through the orders of vertebrate animals, yet their respective analogous organs are much varied in form. For however nearly parts and organs seem to be allied, and parts and organs co-operating to one common end or purpose, yet it will be found that co-operation in function is, that the latter, so far from indicating identity of structure, is in many instances the most dissimilar; while, on the other hand, similarity of texture pervades many parts belonging to different physiological systems.

The first part of study must be the skeleton, which is pretty similar in all animals with a backbone. This will easily be effected through the medium of our figure of the skeleton of the horse, Plate I. Having acquired a knowledge of the various bones, the next object is an acquaintance with the muscles, of which we shall give representations. But besides these, we would recommend dissections of the horse, as the best means of gaining accurate knowledge of the situation and form of the parts. The next step is to study the internal organs, and their comparative dimensions in different species of animals. The situation of the blood-vessels and nerves will then claim our attention. A knowledge of chemistry and pharmacy must likewise be acquired, together with the quantity of medicine which must be administered in various complaints, especially in what doses it should be given to different animals, as its operation much depends upon the length of the alimentary canal, in the various parts, as well as the structure of the stomach, and its size.

Besides the diseases of the horse, we shall treat of those of horned cattle, sheep, swine, and dogs.

ELEMENTARY TREATISE ON FOSSIL CONCHOLOGY.

CHAPTER I.

INTRODUCTION.

Conchology is that department of Natural History which treats of Shells, or the testaceous covering of molluscs, whether they inhabit the sea, land, or fresh water. These shells are composed of carbonate of lime, mixed with certain portions of gelatinous matter.

The collecting and study of shells was cultivated in early ages; but the few scattered fragments concerning their natural history which are to be found in the writings of the ancients, when compared with the more extended and systematic labours of the moderns, are so unimportant and inaccurate, that it would be altogether superfluous to notice them. It appears, however, from the works of Aristotle and Pliny, the great naturalists of Greece and Rome, that the study of conchology was not entirely neglected in their time. It is known, likewise, that admirers and collectors of shells were not then wanting. Scipio and Lælius, we are informed, found a relaxation from the toils and cares of war and government, by indulging in this elegant amusement. Long after their time, however, this department of science was considered a trifling pursuit, which tended to no useful purpose. But a new era dawned on it, and men of genius turned their attention to the subject, and instituted scientific arrangements and classifications under the term Conchology. More recently it was found that this useful science was one of the most important keys to the study of geology; and subsequent researches have proved that to an intimate acquaintance with it, we are indebted for a more thorough knowledge of the strata composing the different geological formations of which the earth's surface consists. The highest authorities of the present day all concur in this opinion. The Rev. Professor Buckland says—"Concurrent with the rapid extension of our knowledge of the comparative anatomy of extinct families of the ancient inhabitants of the earth, has been the attention paid to fossil conchology, a subject of vast importance in investigating the records of the changes that have occurred upon the surface of the globe." And Sir Charles Lyell, in descanting upon fossil organic remains, says—"The testacea (shells) are by far the most important class of organic beings which have left their spoils in the subaqueous deposits, and they have been truly said to be the medals which Nature has chiefly selected to record the history of the former changes of the globe. There is scarcely any great series of strata that does not contain some marine or fresh-water shells; and these fossils are often found so entire, especially in the tertiary formations, that, when disengaged from the matrix, they have all the appearance of having been just procured from the sea."

The great utility of conchology, in a geological point of view, is due to the very perfect condition in which fossil shells are generally found; so much so, that the species can readily be distinguished, which is seldom the case with other fossils. Hence their service in identifying strata. Some of the genera are peculiar to the land, others to fresh water, and others again to the sea, by means of which we are led to a knowledge of marine and fresh-water deposits.

It is a remarkable fact, regarding the distribution of organic remains in the older deposits, that the same forms are found in rocks of the same ages in all parts of the globe. In these strata, corresponding to our lias and oolite, a similar structure has been found in England, Russia, Norway, Southern Africa, the Falkland Islands (which are our antipodes), and even in the Himalaya mountains, and at Fernando Po.

An acquaintance with these, therefore, instructs us that the globe which we inhabit has been subjected to many changes from one condition to another, for we find that entire races of animals have lived, perished, and become extinct, giving place to others with an organic structure adapted to the altered conditions of our globe at different epochs.

Although the fossils which are illustrative of any distinct formation or series of rocks have general characteristics, yet, in the transition from the lower to the higher strata, a difference will be found in the species, and frequently in totally distinct genera, which are peculiar to each succeeding bed.

In the silurian rocks, a striking modification of the distribution of species has been remarked, namely, that in the lowest beds the same species has been ascertained to pervade a much greater thickness of strata than in the higher rocks; from which it would appear, that the molluscs in the former must have existed through much longer periods than any species of the newer deposits. And when we observe that a smaller number of species are to be met with in the older than in the newer rocks, we may assume that new forms were less frequently called into existence during the earlier geological epochs. It is evident, therefore, that each great change to which our globe was subjected, was also marked by the successive production and obliteration of certain races of molluscs.

On a rigid examination of strata, we have incontestable proofs of the progressive development of their animal contents. We find that certain species have been endowed with powers to resist the changes which took place, or must have lived in situations remote from the active agents of destruction; while others, of a high structure, have been swept away in comparatively short periods. And although the older strata, in many situations, contain vast masses of fossil remains, yet, as we have above observed, the number of distinct species is exceedingly limited, as compared with those of the newer deposits.

In the older formations most of the species are silicified, or, as it were, of a stony texture, and become so completely consolidated, and compactly sealed in the matrix, as hardly to be disengaged from it. This is more especially the case with those embedded in the carboniferous and silurian limestones, while in the tertiary, or recent formations, they have undergone hardly any alteration, and are frequently met with so unaltered and fresh, that they appear to have just been taken from their native beds. These are mostly found in soft sandy strata.

Under the head of conchology are included all the molluscous animals, which are, with a few exceptions, provided with a shelly or testaceous covering. They are arranged under two great divisions or classes, viz.: I. Mollusca, which embraces animals inhabiting a single shell, or what have been conventionally termed *univalves*, or mollusca proper, or soft-bodied animals; II. Conchifera, or soft animals, destitute of a head;

these have been designated *bivalves*, because the animals are enveloped in two pieces or valves.

The animals of the first of these classes are more highly organized than those of the latter class, being provided with a head, eyes, and a distinct nervous system; while the latter have neither head nor eyes, and are consequently called *acephala*, or headless animals.

The great variety of forms which obtain in the shells of the first class of molluscs, depends chiefly on the length of the cone. "This ranges through every degree of angularity, from the nearly discoidal—exhibited by some of the patelliform species, in which the cone is so depressed as to form an angle, from the vertex to the margin, of 170 degrees—to that of an elongated tube, extended, in some cases, so much as to become nearly cylindrical, and twisted into almost every conceivable form of spiral, for the convenience, or rather according to the necessities, of the animal. With reference to the spiral shells, this form is the result of an obliquity in the mode of growth, caused by a greater development or increase of one side of the opening, whereby a heliciform direction is given to the shell in the process of enlargement. It is, perhaps, needless to say, that the mode of increase, or growth, of the shell is by the successive deposition of calcareous matter secreted by the mantle, and deposited on the margin of the aperture, and moulded, as it were, upon the soft body of the animal, by which means the impress of every peculiarity is formed, and permanently fixed in the calcareous covering. It may, however, be observed, that some of the exterior ornaments of these shells are formed by an extension or protrusion of the mantle, whereby a fimbriated, and sometimes a spinose, varix is formed upon the margin of the outer lip, producing many varied and beautiful ornaments upon the spiral shell, which, however, have no corresponding characters upon the soft body of the animal. It is from these appearances alone that presumed specific distinctions can be determined; and the characters drawn from them, although they may be considered as somewhat extrinsic to the animal, are the only means afforded to the palæontologist for the determination of species." The recent investigations of Mr. Bowerbank and Dr. Carpenter, in their microscopic examinations into the structure of shells, have shown that there subsists a more intimate connection between the animal and its shell, during its lifetime, than could be supposed to exist by the supposition of a simple addition of earthy or chalky matter deposited upon its cuticle; and that this shelly covering is an organized body, and part and parcel of the animal itself. As yet, however, these most interesting examinations have not been pursued to such an extent as to enable us to found a classification on them. In this treatise, therefore, the groups of genera are based on the various external characters of the shells themselves, which, in a great measure, accords with the variations in structure of the animal inhabitants.

The general classification which we shall follow is that of Lamarck, the celebrated French malacologist. Since his time, a more rigid examination of the characters, as well as a more thorough acquaintance with the animals, besides the discovery of new forms, have rendered necessary the construction of new genera. These are inserted, as far as possible, in the situations most in accordance with his orders and subdivisions. For although much has been done towards the formation of a natural arrangement, yet too much remains to be accomplished before anything like a complete natural classification can be established.

Explanation of the Different Parts of Shells represented on Plates I. and II.—Elementary Fossil Conchology.

Class I.—*Mollusca or Univalves, or such Shells as are complete in one piece.*

They are for the most part spiral, but a few genera are destitute of a regular spire. The principal characteristics of this class are—the general form of the shell, the particular shape of the aperture, the length and construction of the spire and beak, and of the outer and pillar lips.

Apex.—The tip of the spire, or the extremity opposite the base, fig. 1, *a*, and fig. 17, *a*. In shells which are destitute of a regular spire, such as the Patellæ, &c., the vertex of the cone, or highest portion, is thus designated.

Base.—In shells with a beak or rostrum, the base is the extreme end of that organ, fig. 7, *b*, and fig. 17, *b*. In those which are destitute of a beak, it is the lower portion of the body volution, or whorl, fig. 21, *a*.

Body—is the lower volution, or that portion of the shell in which the aperture or opening is situated, fig. 1, *e*, and fig. 14, *c*.

Volutions are the whorls or convolutions of the spire and body, separated by the suture, fig. 7, *e*, *e*, *e*. In *univalve* shells, the structure and number of the volutions forms an important character in describing them, as we have shown above.

Spire—consists of all the convolutions or whorls of the shell but the lower one, fig. 7, *d*.

Suture of the spire is that hollow spiral groove, or, in some species, thread-like line, which separates the volutions, fig. 7, *e*, *e*, *e*.

The Structure of the spire varies according to the plane they turn upon, which is either horizontal, cylindrical, conic, or ovoid. But there are many intermediate forms which cannot be defined. The following, however, are a few examples of the varied structure of the spire:—

Acute spire.—Volutions not deeply divided.—*Terebra maculata*, Plate II., fig. 1.

Obtuse spire.—Volutions well defined, and longitudinally ribbed.—*Murex vitulinus*, Pl. II., fig. 2. Ribbed volutions are likewise exhibited in fig. 10.

Papillose spire.—The tip of the spire or apex terminating in a small papilla or knob is so termed.—*Voluta scapha.*—In this species it will be noticed that the pillar, or inner lip, is provided with oblique plaits or folds. The inner or pillar lip is likewise broadly reflected on the collumella.—*Voluta scapha*, Pl. II., fig. 3.

Mammillated spire—is when the apex of the spire terminates in a breast-like form.—*Cymba porcina*, Pl. II., fig. 4.—This species is an example of a shell with the aperture extending nearly the whole length of the body volution.

Decollated spire.—In some species, when the shell is nearly perfect, the superior or upper volutions of the spire drop off, giving the top a broken appearance, but which, in fact, is a condition natural to the species in its perfect state. In this shell the volutions are nearly flat-sided, and but slightly divided by the sutural line, which is nearly transverse, being an example of shells with the volutions very gradually spiral.—*Balimus decollatus*, Pl. II., fig. 5.

Discoidal spire.—When shells of this genus are viewed with the tip of the spire directly in view, that is, looking down upon it, the spire presents the appearance of a disk or circle, from the convolutions being rolled upon each other like a roll of paper, the entire shell being of a conical form.—*Conus virgo*, Pl. II., fig. 6.

Canaliculate spire—is when the volutions are spiral, separated by a deep and wide channel, and not by the simple groove, or by the thread-like line in various species.—*Eburna spirata*, Pl. II., fig. 7.

Turreted spire.—The volutions are not rapidly spiral, but wind gently, and, being somewhat flattened above, produce the appearance of a little tower or turret.—*Fusus corona*, Pl. II., fig. 8. This spire is both turreted and, coronated.

Coronated spire—is when the superior margin of the body and sometimes with the turnings of the spire, are decorated with upright notches, or bead-like processes, producing a crown-like appearance—as in Pl. II., fig. 8.

Tabulated spire—is when the volutions are nearly horizontal, and quite flattened above. In various instances, such spires have the sides of the volutions nearly flattened.—*Fusus scalares*, Pl. II., fig. 9. This is an example of a spire both tabulated and turreted.

Subacute spire—is when the volutions do not rapidly decrease, as is the case in *Fusus eolus*, Pl. II., fig. 10. This is an example of deeply divided volutions.

Concave spire—is when the volutions are rolled upon themselves around the tip of the spire, or convoluted upon a

nearly horizontal axis, with the whorls apparent both above and below the body volution.—*Planorbis corneus*, Pl. II., fig. 11.

Depressed spire—is when the volutions are much flattened on the spire, hardly rising above the body.—*Purpura lineata*, Pl. II., fig. 12. This is likewise finely exemplified in various species of the genus *Conus*, and Pl. I., fig. 15, *Planorbis cylindricus*.

Reversed or *Sinistral spire*—is when the volutions, viewed with the apex uppermost are in a contrary direction from the ordinary course, or contrary to the convolutions of a common cork-screw, and the sun's *apparent* revolution round the earth. The shells with the volutions reversed are few in number. When held with the spire uppermost, with the front next the observer, the aperture is situate on the proper right of the shell, or opposite the left hand of those looking at the shell; whereas the dextral or right-handed shells have the aperture on the reverse, or left side.—*Lymnœa columna*, Pl. II., fig. 13. This is likewise frequently called a sinistral spire. *Trophon perversus*, Pl. I., fig. 12, is an example of a sinistral shell; and *Fusus longævus*, Pl. I., fig. 7, is an illustration of a dextral or right-handed shell, which is the ordinary form, with few exceptions.

Concealed volutions.—In the genus Nautilus, and some of the Ammonites, the whole of the volutions, excepting the outer one, are invisible and enveloped in it, Pl. I., fig. 18. —*Ammonites Murchisonii.* In the Ammonites, many of the first volutions are concealed, and in most the edges only are seen, Pl. I., figs. 4 and 6.

Involute spire.—The same as concealed, where the volutions are enveloped in the body, as exemplified in the genera Nautilus, Bellerophon, &c.

Aperture—is the opening of the shell by which the animal protrudes itself, in most species situate on the proper left side of the shell, Pl. I., fig. 7, *f*. These shells are called dextral, or right-handed, while those with the aperture on the right side are called sinistral, or left-handed, as in Pl. I., fig. 12, *c*, as more particularly described in reversed and sinistral spire.

It will be seen that the form of the aperture is very different in the various genera, and is of much use in describing shells, viz.:—

Transversely oval aperture.—*Stomatia inconspicua*, Pl. II., fig. 14.

Longitudinally oval aperture.—*Murex frondosus*, Plate II., fig. 19.

Orbicular or *circular aperture.*—*Turbo smaragdus*, Pl. II., fig. 15.

Pyriform aperture.—*Phasianella varia*, Pl. II., fig. 16.

Semilunar, or *half-moon shaped aperture.*—*Helicina festiva*, Pl. II., fig. 17; also that of fig. 11.

Superiorly-contracted aperture.—*Auricula auris*—*Midæ*, Pl. II., fig. 18.

Trigonal aperture.—*Trochus zizyphinus*, Pl. II., fig. 20.

Semicircular aperture.—*Natica monilifera*, Pl. II., fig. 21.

Linear aperture.—Narrow, extending the whole length of the shell.—*Cypræa tigris*, Pl. II., fig. 22. This aperture is toothed or denticulated on both sides.

Turned-up aperture.—This is bent upwards, is situate on the upper side of the volutions, and looks towards the tip of the spire, contrary to almost all other univalves, their aperture for the most part opening from the base.—*Anastoma depressum*, Pl. II., fig. 23. This is an example of an aperture toothed or denticulated on both the outer and inner, or pillar, lip.

Outer Lip, or Peristome—is the left margin of the aperture, or final termination of the body volution, Pl. I., fig. 12, *c*; Pl. II., fig. 1, *l*; and fig. 7, *f*. In some instances, the outer lip is reflected, and in others inflected. Indeed, this is subject to many variations in form.

Dentated outer lip.—*Rostellaria provisii*, Pl. II., fig. 24. This is also an example of a straitened aperture.

Alated or *winged outer lip.*—*Strombus Auris Dianæ*, Pl. II., fig. 25. This is likewise an example of an enamelled exterior, or thickening of the columellar lip, which frequently extends itself to the spire in front, and conceals the volutions.

Horned outer lip.—This horn-like process is found in the genus *Monoceros narval*, Pl. II., fig. 26, as well as in other species of this genus. It is an elongation of the internal enamel of the outer lip, near to the base of which it is situate in the various species.

Digitated outer lip.—These spinous processes always emanate from the external surface of the outer lip, contrary to those of the preceding kind.—*Ranella spinosa*, Pl. II., fig. 27.

Reflected outer lip—as exemplified in *Helix senegalensis*, Pl. II., fig. 28.

Internally and externally denticulated outer lip, as shown in *Triton cutaceum*, Pl. II., fig. 29.

Involute and denticulated outer lip, as in *Cypræa tigris*, Pl. II., fig. 22.

Inner, or Pillar, Lip—likewise called the Columellar Lip—is situate at the base of the body in front, and bounded by the aperture on its left, Pl. I., fig. 7, *g*, and fig. 21, *c*.

Pillar, or Columella—is that winding process which runs through the centre of the shell inside, from the base to the apex, and appears to be the support of the spire.—*Buccinum undatum*, Pl. I., fig. 26, *a*, *a*, *a*.

Columellar Lip, with oblique plaits. *Turbinella umbilicaris*, Pl. II., fig. 30.

Columellar Lip, with parallel plaits, *Cassis tuberosus*, Pl. II., fig. 31.

Tortuous Pillar, or *Columellar*, *Lip.*—*Ancillaria glabrata*, Pl. II., fig. 32.

Continuous or Entire Outer Lip, Pl. I., fig. 21, *a*.

Umbilicus.—That concave perforation or hole situate at the base of the body, and, in some instances, at the back of the reflected inner lip, fig. 14, *a*. A deep umbilicus on both sides is characteristic of the genus Goniatites, Pl. I., fig. 19, *a*, *b*, as in G. reticulatus, of which the figure is a section, taken transversely.

Beak, or Rostrum.—That process which is prolonged beyond the base of the body in many genera, short in some, and greatly lengthened in others, Pl. I., fig. 7, *i*. The length and peculiar form of this organ, is an important feature in the character of various genera and species.

Recurved Beak.—*Cerithium aluco*, Pl. II., fig. 34.

Recurved Varicose Beak.—*Nasa clathrata*, Pl. II., fig. 35.

Truncated Beak.—*Fasciolaria trapezium*, Pl. II., fig. 36.

Spiral Shell, with the volutions disconnected, *Spirula Pyronii*, Pl. I., fig. 27.

Canal, or Gutter, is the internal hollow or groove inside of the beak, formed by an extension of the outer and inner lips, Pl. I., fig. 7, *k*.

Closed Canal.—*Typhis hemitripterus*, Pl. II., fig. 33.

Chambers.—Internal portions of the shells of the genera Ammonites, Nautilus, Orthoceana, &c., and which are divided by septæ, or walls, Pl. I., fig. 3, *a*, *a*, *a*.

Septæ, or Partitions, are those walls or partitions which subdivide the internal portions of shells of the Nautilus, Ammonites, &c., into distinct chambers, Pl. I., fig. 3, *b*, which is a section of the Nautilus.

Nautilus Pompilius.—This is a section of the shell, exhibiting the internal structure; Plate and fig. *a*, *a*, the chambers; *b*, *b*, the septæ or partitions; *c*, the siphuncle or tube, which traverses the entire of the chambers, from the aperture to the inner convolution. The use of this organ will be particularly described when treating of the general character of the animal, which will likewise be more minutely noticed in its place.

Outer Chamber.—In the genera Nautilus, Goniatites, Ammonites, &c., this portion of the shell is occupied by the animal. Ammonites obtusus, Pl. II., fig. 4, *a* to *b*. In some instances the outer chamber extends as far as *i*.

Lobes and Sinuses.—Pl. I., fig. 2, represents those parts of a Goniatite: *D*, the dorsal region; *L*, the lateral region; *M*, the marginal or umbilical region; *a*, *b*, *c*, the lobes; *e*, *c*, *e*, the sinuses; *S*, the siphuncle; the barbed arrow-head points towards the aperture, and marks the centre of the lobes and sinuses

We give a representation of Ammonites heterophylus, to exhibit all those parts—viz., *a*, the siphunele; *b*, the dorsal lobe; *c*, the dorsal saddle; *d*, the superior lateral lobe; *f*, the inferior lateral lobe; *g*, the ventral saddle; *h*, the ventral lobe; *i*, *i*, *i*, axillary lobes; *k*, the baek or ambit.

Slipper-shaped Lobes, as found in Goniatites Henslowi, Pl. I., fig. 6.

Ventral Lobes.—These are exhibited in a cast of a chamber of Nautilus, ziczag, and shows their deep curvature backwards, Pl. I., fig. 8; *s*, the sipbuncle.

Lobes and Saddles, as exhibited in a back view of Goniatites sphæricus, Pl. I., fig. 13.

Transverse Plates, as shown in a portion of Ammonites ventricosus, Plate I., fig. 11, *a*, *a*; the siphuncle, *b*.

Siphuncle, a small circular tube, which perforates the septa in shells of the genera Nautilus, Ammonites, Goniatites, Orthocera, Belemnites, &c. Its opening or aperture is situate in the last or external volution of the above genera. Its use is particularly described in the generic account of Nautilus and Ammonites. See Plate I., fig. 3, *c*, fig. 8, *s*, fig. 11, *b*, fig. 4, *c*, *d*, *e*, *f*, *g*, *h*, fig. 17, *a*, fig. 19, *c*, and fig. 9, *b*, *b*.

In the genus Nautilus, this process is always situate in the middle of the convolutions, as in fig. 3, Pl. I. In Ammonites its position is at the back or ambit of the volutions; and in Endosiphonites it is situate on the inside of the aperture, close to the body volution.

Sheath, in the genus Belemnites, is the external envelope of the shell, Pl. I., fig. 9, *a*. In this genus the air-chambers are divided by septa, placed transversely, as in other genera of this order.

Fibro-calcareous Sheath of a Belemnite, Pl. I., fig. 9; its apex is at *c*. This process is called its cone. Fig. 10 is a section of an Orthocera.

Front is that part of the shell in which the aperture is situate, Pl. I., fig. 7, *l*.

Back, the contrary of the above, Pl. I., fig. 26, *b*.

Keel, or Carina, that projection which is met with in various Ammonites and other shells, Pl. I., fig. 18, *a*.

Varices are longitudinal ribs, which are formed by the periodical growth of shells. These have been severally the outer lip, to which the animal has added from time to time. Varices prevail in the genera Triton, Muxes, and Buccinum. Some species have never more than a single *varix*.

Ribs are longitudinal or transverse processes, which are elevated above the external surface of shells, Pl. II., figs. 10 and 18.

Plaits are folds formed on the columella or inner lip of certain shells, as in the genera Mitra, Voluta, Oliva, &c., Pl. I., fig. 21, *c*, and figs. 3, 18, 30, and 31, of Pl. II.

Teeth are small processes situate in the outer lip, and sometimes in the inner lips of univalve shells, Pl. II., figs. 22, 23, 29, and 31.

Operculum, or Lid.—A shelly or horny process attached to the foot of the animal inhabiting several genera of univalves, and which closes either wholly or partially the aperture or opening of the shell, Pl. I., fig. 16, and Pl. II., figs. 37 to 42.

Multispiral operculum, Pl. I., fig. 16, and Pl. II., fig. 37.
Articulated operculum, Pl. II., fig. 38.
Radiated operculum, Pl. II., fig. 39.
Lamellated operculum, Pl. II., fig. 40.
Concentric operculum, Pl. II., fig. 41.
Unguilated operculum, Pl. II., fig. 42.

Epidermis.—The external skin or cuticle which invests many species of univalves, and appears destined to protect the shell from injury.

Class II. Conchifera—Bivalves.

Bivalve shells are those which consist of two pieces or valves; such as the oyster, cockle, mussel, &c. These are connected by a cartilaginous proeess. In some species both valves are of equal size and form, while in others they are very dissimilar.

Equilateral Bivalves are those in which both sides are alike, as exemplified in shells of the genus Pecter, Pl. I., fig. 20.

Inequilateral Shells are those in which the sides are dissimilar, Pl. I., figs. 22, 23, and 25.

Right Valve is that valve which, when viewed from the inside, with the umbo uppermost, has the anterior slope pointing to the right hand.

Left Valve, the reverse of the above, or with the anterior slope pointing to the left hand when viewed from the inside, Pl. I., fig. 22.

Anterior Slope, or Side, is that side of the valve in which the ligament is situated. In looking at the anterior slope in front, the beaks of the shell retire from the observer.

Posterior Slope, or Side, is that part of the valve opposite the anterior side; or, when viewed in front, the beaks point to the observer.

Umbo, or Beak, is the superior portion or point of the valve, situate above the hinge, and which has been termed the apex. This part is the nucleus from which the enlargement of the valves takes place, commencing in a small concentric circle, and continuing untii the completion of the shell. Plate I., fig. 20, *b*, fig. 22, *a*, and fig. 23, *b*. In some species the umbones are flat and hardly visible, while in others they are long and curved, as in Plate I., fig. 33, Isocardia cor.

Hinge—that portion of the shell situate below the umbones, or beaks, and at which part the valves are united, and acting as a fulcrum for opening and shutting them. Some hinges are simple, and destitute of teeth; while others are complex, and are furnished with teeth, which each lock into cavities, formed for their reception, in the opposite valve. Plate I., fig. 22, *c*.

Teeth of the hinge are processes which are situate in the hinge of many bivalves. These are extremely variable in form and number, and are of much use in the generic and specific distinctions in bivalves. In some species they are large and single, (Plate I., fig. 25, *a*); while in others they are numerous and small, (fig. 23, *a*); and, for the most part, they lock into cavities in the opposite valve, there being generally a tooth and a void alternately.

Primary or Cardinal Teeth are always situate in the centre of the hinge, immediately under the umbo, or beak. They are either broad and large, or elevated and acute. Plate I., fig. 22, *c*.

Erect Teeth are exemplified in the genera Mya and Panopæa. They generally protrude beyond the edges of the valves, and are not placed laterally. Plate I., fig. 25, *a*.

Lateral or Divergent Teeth are those which diverge from the umbo. They are generally long and flat, and seldom erect. In some species they are double in one valve, and receive those single ones in the opposite valve between them. Fig. 22, *d*.

Numerous Teeth are exemplified in the genera Pectunculus Cucullæa, and fig. 23, *a*.

Ears.—Those processes on each side of the beak, (fig. 20, *c*, *d*.) When these ears are not well defined, they are termed auricles.

Superior Ear.—Fig. 20, *d*.

Inferior Ear.—Fig. 20, *c*.

Margin.—The extreme edge of the whole valve, or the circumference all round.

Crenulated Margin.—Those fine numerous notches which invest the edges of many bivalves, particularly in the genera Cypricardia and Cardium. Fig. 22, *e*, *e*.

Length is taken from the hinge or umbo, (fig. 20, *b*,) to the opposite extremity or base of the valve, *a*, *a*. Bivalve shells are termed longitudinal, when their length is greater than their breadth. For example, the common mussel is a longitudinal shell, as are also the shells of the genus Pectea, or scallops. Fig. 20.

Breadth, from the extreme of one side to that of the other, (fig. 22, *f*, *f*.) It is not uncommon for the breadth to be greater than the length, as in the genus Anodon, or fresh-water mussels. In this case they are termed lateral or transverse shells.

Striæ are fine or coarse thread-like lines, which ornament the outside of shells, and sometimes the inside of both bivalves and univalves. When the striæ are indistinct, as if obliterated, they are said to be obsolete. The charaeter and disposition of the striæ are of much consequence in the discrimination of

species. When these striæ are both longitudinal and transverse, they are said to be decussated striæ.

Muscular Impressions.—These are of much use in the generic and specific distinctions of bivalves. The most conspicuous are those of the adductor muscles, by which the valves are opened and closed. Fig. 22, *g*, *g*.

Pallial or Mantle Impressions.—In all bivalves, in which there are two muscular impressions, there is a depressed line, to which the mantle of the animal is attached, extending from the upper and inner edge of one muscular impression to the other. This line is frequently deeply sinuated on the posterior side. Fig. 22, *n*.

Ribs, or Costæ, are longitudinal or transverse protuberances, running from the apex to the base, as in fig. 20, *a*, *a*. These are called longitudinal ribs; and when running in an opposite direction, they are termed transverse ribs, or across the valves from side to side.

Base.—That part of the shell opposite the umbo. Fig. 22, *f*.

Accessory Valves are small testaceous or shelly plates, at the back of the hinge of the genus Pholas. Fig. 31, *a*.

Inequivalve is when one valve is larger than the other, as in the genera Terebratula, Corbula, &c. Fig. 31, *a*.

Loop.—In the genus Terebratula, there is an internal process so termed, which is attached to what is called *crura* in the larger valve. This is sometimes short, while at others it nearly extends to the base of the valve. Fig. 32, *a*, *a*.

All other terms used in the science will be defined in a glossary at the end of the treatise.

HORTICULTURE.

CHAPTER VII.

THE STORING AND PRESERVATION OF GARDEN PRODUCTIONS.

In order to understand the right manner of preserving fruits and vegetables, it is necessary to have a clear idea of some of the more important facts ascertained by science relative to the putrescence of vegetable (and we may observe that the same holds true of animal) matters. It is almost unnecessary to say, that the great object desired in storing garden productions, is the avoidance of putrefaction or decay.

As long as a living structure (it is the same with animals as with plants, with which latter only we have here to do) is alive and exists, the elements that compose it—provided, of course, that it be an article of food—are so joined together as to form starch, sugar, gluten, and the like, all of which are palatable, and likewise nutritious. Farther, if we destroy the life of any living structure—as, for example, when we dig up a potato plant, or cut down a wheat stalk—the life for a little time remains about it, and the elements composing it still retain their vitality, and still form these nutritious and agreeable compounds. This, however, is only for a time. Green leaves, as those of spinach, for instance, soon cease to continue as they were, and even dried leaves, roots, and seeds always tend to form new combinations. This is caused by the elements composing them joining with the elements of air and water around them, and forming compounds which are not palatable, and which cannot afford any nutriment to man or animals. This process is called putrefaction, or the putrefactive fermentation, or rotting. The starch, for example, of the potato or the sago, that is pleasant to our palate, and which, when swallowed, is turned into animal fat, is converted by putrefaction (at least in part) into carburetted hydrogen, which is not palatable, and which cannot be digested; and the gluten of the wheat plant, which is sapid, and which can be converted by the digestive organs into muscle, is, by this fermentation, mainly resolved into ammonia, which is unpleasant to our senses, and altogether non-nutritious.

The art of man, however, can alter and modify this tendency of the structure of animals and plants to run into the putrefactive fermentation, and it is now nothing uncommon to eat fruit or meat, or to drink milk, that has circumnavigated the globe, and all of which are as fresh as the day they were taken on board. When it is considered that, in this climate especially, the time during which vegetation can go on is limited, that but one crop of corn, fruit, and potatoes can be got in a year, the preservation of vegetable food evidently becomes a very interesting and important subject.

A very curious fact connected with putrefaction is as follows:—Any structure passes more rapidly into this putrefactive fermentation, if placed in contact with any putrid substance. One rotten apple will, for example, cause a bushel of sound ones to become rotten also. We have rules very analogous to this in the two other fermentations—to wit, the vinous, *i. e.*, where sugar is converted into spirit; and the panary, *i. e.*, where flour is converted into leavened bread. In both these cases, a little ferment communicates the tendency to fermentation to the whole mass.

When we consider that water is necessary for putrefaction, one obvious mode of preventing putrefaction is, to deprive a substance of its water. As air is likewise indispensable, another plan is to keep it off. Keeping a garden product fresh, is to contrive to hinder the air from having any access to it. Farther, there are certain substances called antiseptics, that have the remarkable property of preventing putrefaction in animal and vegetable structures to which they are applied. The most important of these, are salt, sugar, and vinegar. Being now in possession of these facts, the following summary of the storing and preserving of garden productions will be intelligible.

Some vegetables, as peas, beans, salads, green gooseberries, &c., are required for the kitchen before they are ripe, and are usually consumed the day or the day after they are gathered. Such as these may, however, if desired, be preserved for a considerable time, if placed in a part so cool as nearly, but not quite, to freeze them. Freezing them altogether would effectually preserve them from putrefaction, but freezing destroys the starch which most vegetables contain. The *rationale* of the antiseptic effect of frost is plain enough. By converting the water contained in vegetables into ice, it effectually takes away the moisture, and thus renders decay impossible. The inhabitants of northern countries preserve great quantities of meat by freezing it, and in Scotland it is, or was, before the railways, thus kept fresh for the London market. If such a plan be tried with green vegetables that contain little starch, as is the case with green gooseberries and peas, they must be thawed very slowly. This is best done by immersing them in cold water. If this precaution be neglected they pass on, on being thawed, to putrefaction with extreme rapidity; and even if cooked before this change can take place, they have an unpleasant taste.

But the great majority of those managing a small garden, such as we always in this dissertation keep in mind, have not ice. The following mode of preserving green gooseberries, currants, or peas, is sometimes quite successful, and probably would always be so, if the necessary conditions were attended to. The fruit or peas should be gathered in dry weather, and, if convenient, exposed for an hour or two to the sun. The gooseberries or currants must not be pulled by hand, but be cut with scissors, and the absence of a single bruised or wounded one be carefully ascertained. They should then be dropped carefully, one by one, into green wide-mouthed bottles. The mouths of these are then to be corked, and the corks covered with resin. The bottles should then either be kept in a cool cellar, or, what is much better, buried three feet deep in a trench with the mouths downward.

About forty years ago, Mr. Appin received from the French Government a reward of 12,000 francs, for a new method of preserving, not only vegetables, but all kinds of meat, fish, or milk. This method has been found to be quite successful, and articles of food prepared according to it will keep an indefinite time—and such are now constantly used on board ship. They are also now sold at many of the shops. The prices, however, are high. Roast beef, for example, is charged two shillings a pound; green peas, two shillings a pint; cream, two shillings and twopence a pint, and so on. The process, nevertheless, is not a very difficult one.

It essentially consists in altogether preventing the access of air. First of all, by boiling or otherwise cooking the viand intended to be preserved, the air is driven from the internal parts of it. Another purpose is likewise served by this boiling. Almost all articles of diet, whether animal or vegetable, contain a liquid substance called albumen, of which the white of egg is a very good example. When this liquid albumen is heated up to 180° (a heat much less than that of boiling water), it coagulates and becomes solid. It is found by experience, that solid albumen is much less liable to pass into the putrefactive fermentation than when fluid; and hence it is, that in this process the cooking the article intended to be preserved makes it keep the better. The next thing to do, after having driven out the internal air, is to put the substance intended for preservation into something that will effectually keep out the access of external air. This is managed as follows.

We should first of all, however, observe, that in the first boiling, vegetables should not be nearly so much boiled as when they are intended for immediate use. So doing would make them far too soft.

The parboiled vegetable, or the boiled meat, is carefully packed in a tin canister. In the case of meat, strong gravy is poured upon it; but when vegetables are thus preserved, we believe that water, with a little salt in it, is found to be the best. The object in both cases is to fill up interstices. The canister being *thoroughly* (this "thoroughly" is the essential thing) full, a tin cover is carefully soldered over the top, leaving one little aperture. The canister is then put into boiling water, the heat of which drives off what air may be amongst the provisions, and likewise expands the ingredients. While thus hot and expanded, the aperture is soldered up, and the whole allowed to cool. If the sides of the canister collapse a little, it indicates that the air has been successfully expelled, and is a proof that the operation is complete.

In preserving in this manner various articles, peculiarities will be found to exist in the necessary details. Thus, in so managing asparagus, it is necessary to avoid allowing the water in which the canister is placed to do more than just boil. All these details can only be learned by experience. Green peas are usually the most difficult to manage, as they have a tendency—it is difficult to say why—to run into a pulp.

While upon this point of our subject, we may notice a substitute for green peas. Green peas contain sugar, which sugar, as the pea ripens, becomes converted into starch. When this ripe pea is put into the ground it begins to germinate, and in the process of germination the starch is converted back again into sugar. By soaking old peas in water they may be made to germinate, and if cooked at the right time they have a resemblance to green ones.

With regard to the gathering and storing of apples, the following seems to be the most important rules:—All fruits have the power of ripening a little, although very slowly, when separated from the trees on which they grow. Hence, by gathering them before they are quite ripe, they in time become very palatable, and we thereby prolong the time they tend to occupy, before they become putrid. It is considered that, in general, it is proper to gather them eight days before they are ripe. Every apple (and these remarks apply equally to pears) should be removed separately, and, in doing so, the stalk should be cut with a pair of seissors. Fruit intended for keeping should never be shaken off the tree, still less beat down by a pole, as is sometimes the custom. So doing is sure to bruise some of the fruit, and the bruised bit will not only decay, but communicate the propensity to putrefy to every one near it. They should be gathered on a dry day, and if this is not practicable, they ought to be carefully dried with a cloth. If this last be neglected, mould will be very apt to grow upon them. The ends of the stalks of the finest apples and pears should be dipped in melting sealing-wax, to prevent any of their delicately flavoured juice from escaping.

It used to be the custom, when apples and pears had been gathered for strong, to pile them in heaps. After they had been in these for a time, their temperature was gradually raised, and they became covered with moisture or vapour. Exactly similar phenomena may be seen in haymaking. Of the true nature of this process of "sweating," as the country people call it, little is known. In practice, it has of late been condemned, and is now rarely carried into effect.

After the fruit is gathered, it should be stored in a cool but dry place, where the rays of the sun do not enter. Care should be taken that no decomposing matter, as wet straw, damp sawdust, or the like, be present. Apples and pears are great absorbers of any unpleasant odour, and the smell especially of damp straw is sure to spoil their flavour. They should be examined from time to time, in order to ascertain if any of them is beginning to decompose. If such be the case, it should be carefully removed to prevent its corrupting the others.

The still finer apples and pears are even farther protected by being kept from the air. This is done by packing them in sand or moss, or wrapping them in paper. When they are gathered unripe, it would seem proper to allow them to be exposed to the air for a few days, as fruit cannot ripen until it have access to the oxygen of the atmosphere.

Common baking apples and pears may be preserved quite well, by burying them in quantities of five or six bushels in pits in the ground.

Cherries, plums, apricots, &c., may be preserved a few days, by gathering them before they are quite ripe. In plucking these fruits, great pains should be taken not only to avoid bruising them, but to avoid rubbing off the fine varnish or "bloom" which envelopes them.

Walnuts and filberts should be dried, and then packed in boxes with thoroughly dried sand.

Root crops are easily preserved throughout a great part of the winter. They require moderate seclusion from the air, and that they be not exposed to frost. Potatoes generally keep quite well in a cellar, covered with mats. If a large quantity is kept, they must be stored in pits. Formerly, potato pits were really pits or excavations; but now it is the custom to pile the potatoes on the surface, cover them with straw, and upon this to apply a layer of earth from six to ten inches thick. In lifting potatoes for strong, care should be taken not to injure them, and it is better to leave a little of the soil attached to them.

Turnips may be preserved in the same manner as potatoes; and in preserving them it is necessary to remember, that the top root, should not, as is too often the case, be cut. If it is, the juice of the plant exudes, and decay is induced.

In preserving carrots and beet-root, it is usual to protect them from the action of the air by packing them in sand, and when so packed in a cellar or root-house, they keep very well until the end of March.

There is no occasion to keep parsnips from the frost. Indeed, as we before said, they are not good until they have been exposed to a reasonable amount of it. Jerusalem artichokes keep very well placed upon a heap, upon the root-house floor.

Cabbages, and even broccoli, may be preserved a considerable time by pulling them up and hanging them, root uppermost, from the roof of a cool and dark apartment.

Onions are best preserved by drying them in the sun for a day or two, then gently rubbing the outer husks off, and then tying them up in bunches of two or three, by passing packthread tightly round the stalks. It is usual to keep the string continuous for a yard or so. If the onions in spring begin to sprout, it is recommended to touch their roots for a second with a red-hot iron.

Any vegetable may be preserved in a strong brine, made of four pounds of salt dissolved in a gallon of water. Salt, however, is but little used in this country for keeping vegetables. On the continent, kidney beans are extensively preserved in this manner. The following is a Dutch plan of keeping these vegetables, which, to the personal knowledge of the writer of this, answers very well:—The French beans, or scarlet runners (it is immaterial which), are gathered before they become stringy, and cut in long slices; a layer of these is put into a cask, and covered with a layer of salt—then another layer of beans, and another of salt, until the required quantity is stored. A fermentation soon takes place, of the nature of which nothing would seem to be known, and which throws to the surface a scum. At the end of about six days from putting the beans

into the cask, this scum must be poured off, a fresh supply of salt applied, a cloth put on to keep out the air, a board with a heavy weight on it placed over the beans to compress them. French beans, preserved in this manner, require, before they are cooked, to be soaked in water, and they are best dressed with gravy, or a little butter.

In Germany, too, it is common to preserve cabbages for winter use, such preserved cabbages being called sour krout. To prepare this, salt is sometimes used as the sole antiseptic, and sometimes vinegar is added to the salt. The following method is extensively followed:—The cabbages that are wished to be preserved, are cut into tolerably thin slices, and spread on a cloth in the shade. A barrel is selected that has held vinegar, and the head taken out. Upon the bottom is put a layer of salt, then a layer of sliced cabbages mixed with a few carroway seeds, and sometimes a little pepper and oil. Then comes another layer of salt, then more cabbages, and so on until the cask is filled; very heavy pressure is then made upon the whole. Those housewives who are particular, put heavy stones upon a board placed over the cabbages, but the majority have a strong peasant to jump upon the mass with his heavy sabots or wooden shoes. A similar fermentation to the one mentioned a little above takes place, and the scum that arises must be poured off, a little fresh salt added, and the casks carefully fastened up.

When vinegar is used in this country as an antiseptic, spices are usually added, and the vegetable so preserved is used more as a condiment than as an article of diet. Most vegetables, as cauliflowers, cucumbers, &c., contain so much water in their composition that they dilute the vinegar to such an extent as to destroy its antiseptic properties. This might, perhaps, be avoided by using a more concentrated acid, but in practice this difficulty is otherwise obviated. Common salt has a great affinity for water. We see an instance of this, if a salt cellar be put into a damp place, *i.e.* a place where the air has some water mixed with it. In such a case the salt takes the water from the air. In like manner, if salt be thrown upon these watery vegetables, their water, or a portion of their water, joins the salt. If vinegar be then added (the briny fluid being of course poured off), they are preserved from decay, or pickled.

All pickling operations should be conducted in either glass, china, or unglazed stoneware dishes. Any metallic substance, or any glaze containing lead, imparts poisonous properties to the vinegar. Earthenware glazed with salt is unobjectionable.

Sometimes pickles are made extremely hot with spices, and occasionally other substances are employed to flavour them. Thus we believe that the shoots of the young elderberry tree, and also a few elderberry flowers, before they have just opened, are necessary for piccallily. Of late, instead of ordinary vinegar, diluted pyroligneous acid has been much employed for pickling purposes. It possesses this advantage, that it can readily be made any strength required.

In the case of some ripe fruits, as cherries, peaches, plums, apricots, &c., spirit is employed as the antiseptic. These fruits should be gathered before they are quite ripe, and soaked for a few hours in the hardest water that can be obtained. The best kind of spirit to use, is that called "silent spirit," which is a spirit that has no flavour. To each quart of spirit, five ounces of sugar are to be added. The sugar is employed to render the mixture more palatable. Nevertheless, sugar is itself a powerful antiseptic; and this brings us to consider the last mode of preserving ripe fruits of all kinds, viz. by means of sugar.

Substances are preserved in various manners by sugar. Pulpy fruits, as apricots, plums, apples, pears, &c., are often preserved in sirup. The great art in making sirup, is to hit the proper strength. If at all too strong, the sugar will crystallize, and spoil the fruit. On the other hand, if too weak, it will ferment, and eventually become sour. It is found that two parts of double-refined sugar to one of water, and the mixture boiled a very short time, affords a sirup of the proper strength. If the boiling be allowed to go on too long, the water is evaporated, and the sirup becomes too strong.

All the fruits that we have enumerated in the preceding paragraph, require to be boiled before being put into the sirup. This proceeding softens their textures, and allows the sirup to permeate them. The flavour of some fruits—as, for example, that of pine apples—is destroyed by boiling. To preserve such, the proper plan is to pack the sliced fruit in alternate layers with sugar, and then to expose the vessel containing the mixture to gentle heat, by holding it in a jar of hot water. The sugar gradually melts, and the scum rises to the top. This must be skimmed off, and the mouth of the jar made impervious to the air, by being covered with wet bladders carefully tied, or by a cork and wax.

Some fruits, as cherries and currants, are occasionally preserved dry. They are treated just in the same manner as those intended to be preserved in sirup, and then dried on a sieve in a very moderately-heated oven. They require to be turned every six hours, and to be carefully dusted with powdered sugar.

LECTURES ON SCULPTURE.

BY SIR RICHARD WESTMACOTT.

LECTURE III.

SCULPTURES OF THE PARTHENON—ANCIENT PRINCIPLES OF COMPOSITION.

The battles of Salamis and Marathon having secured to the Athenians their liberty, and placed at their disposal immense wealth, the temples, which had been destroyed in the Persian invasion, were rebuilt, and gratitude to Minerva, their tutelary divinity, suggested the erection of an edifice to her honour, which in the beauty and costliness of the materials, as well as in every refinement which the advanced state of the Fine Arts could supply, should surpass any that had before existed in Greece. With this feeling the Parthenon was built, and was enriched with the most perfect specimens of sculpture—illustrating the Panathenaic festival which had been instituted in honour of the goddess, and other subjects, mythological or historical, appropriate to such an edifice, and calculated to render it at the same time, a worthy monument of the gratitude and piety of the Athenians, and of the political rank to which their valour and talents had raised their country.

To unbounded magnificence, and the spirit of sublimity which animated Pericles, were happily united a refined taste and equal judgment. Phidias, to whom was confided the accomplishment of this vast design, employed Callicrates and Ictinus as the architects: Alcamenes, Agoraeritus, Colotes, and other artists of equal eminence, were associated with himself in its external decorations: while the statue of the goddess for the interior of the temple was reserved to be the work of his own hands. In contemplating what has been spared to us of these extraordinary examples there is an irresistible admission of their excellence. Of no other works has superiority been assented to with the same degree of unanimity; and certainly of all the known productions in art, the sculptures of the Parthenon approach nearest to perfection. On examining these marbles, we are at a loss to decide whether the beauty and variety in the arrangement of the several parts, the choice of form, or the skill exhibited in the execution, most demand our admiration. The great care bestowed upon the latter, namely, the execution, strikes us with more astonishment when it is remembered that, in many instances, more especially in the eagles of the pediment, the greater part of the work must, from the position of the sculpture, have been totally out of sight; and those portions which could be fully viewed, were, at the nearest point of view, not less than 120 feet from the spectator. We learn, from the authority of several writers, that a custom prevailed of exposing works to public view before they were placed in the situations they were destined to occupy; and the ambition the artist would naturally feel to excel, may be adduced as a sufficient motive for the extreme finish throughout of these statues. But, we may reasonably infer, that a much higher feeling—the sanctity of the edifice, and the glory of being associated with a work proposed to surpass all others in magnificence, and to be raised in honour, not only of the divinity presiding over Athens; but, at the same time, the immediate protectress of the Arts themselves—would prevail over every other minor motive to call forth the highest energies of the artist. The form of this temple was hypæthral, or in part open to the

sky. It was about 200 feet in length, 100 in breadth, and 53 feet in height to the base line of the tympanum, and 72 feet to the apex. The height from the ground to the metopes and Panathenaic frieze was about 46 feet. The latter received its light chiefly by reflection, and from between the columns of the peristyle. The entrance was at the east end; a custom, it appears, observed in all Athenian temples, in contradistinction to the Dorian Greeks, who entered at the west, and addressed the Deity with their faces towards the east, as is generally practised at this time, in Christian communities.

The sculpture which decorated the eastern pediment represented the birth of Minerva; that of the western, the contest of Neptune with Minerva for the guardianship of Attica; while the goddess herself, in all the gorgeous display of chryselephantine sculpture, was placed at the western extremity of the interior; she was dressed in a tunic which reached to the feet, and over it were thrown the chlamydion and the peplos.

In reviewing the sculpture belonging to these pediments, we can consider them abstractedly only, and as works of Art; the heads in all but one statue being either lost, or too much mutilated to allow of any observations or reasoning on individual character. The eastern pediment supplies this exception in the recumbent figure reclining on a rock, covered with a lion's skin. Whether it represents Theseus, or according to a later hypothesis, Cephalus; or whether the Idæan Hercules be personified in this statue, the distinctive character which would apply to either of these heroes is fully developed. Beauty, breadth, and strength, are united, conveying to the mind the powers of a god, without the distinctive quality which stamps him, in the ideal treatment of parts, his equal. The Professor observed, that there perhaps was no statue in existence which more fully exemplified the remarks he had made in his first lecture upon the adaptation of peculiar forms and treatment to the representation of subjects of a certain class or character, than that in the Elgin collection, which has hitherto been called the Theseus.

In considering the draped groups,—the one supposed to represent Ceres and her daughter Proserpine, the other two of the Fates, (the third Fate being presumed to be intended in a fragment of a seated figure removed from the same pediment)—we can reason upon them only in reference to their harmony as compositions, or to their consent of form with action or position.

Referring to the Fates more particularly, it will be observed that as civilization advanced, taste became more refined; the elegantly-minded Greeks abandoned the monstrous forms which early fable had associated with destructive or offensive moral qualities, and personified even the Gorgons and Harpies under pleasing forms; characterizing their properties by their actions, and by appropriate attributes.

These groups are so nicely balanced, that it is difficult to make any distinction as to their comparative merits; it is in certain qualities only, that they differ; in their conception they are evidently the emanation of the same master mind.

The draperies of the Ceres and Proserpine are generally of a broader style than those of the group of the Fates, assimilating more with the treatment of the statue which has been called Iris, in the same pediment; both these works appear to be from the hand of the same artist.

The peculiar grace in the repose of the recumbent figure in the group of the Fates, the arrangement of the limbs, and the breadth and grandeur of its style, claim particular regard. She is represented in all the majesty of nature, and in the meridian of beauty; but a beauty of a lofty character, which, while it calls forth our admiration, seems also to command our respect.

There is no example, in the whole range of Grecian art, that displays more unequivocally the knowledge possessed by the ancient artists of the construction of the human figure, or shows more decidedly their judgment in the choice of position for the development of its physical elements, and, at the same time, their great skill in execution,—in which quality it surpasses all contemporary and later productions,—than the statue presumed to personify the Ilissus. In the contemplation of this work, Art is forgotten in the truth of the imitation. No statue in the antique offers stronger motives for reflection. Let those who doubt the research of the ancient artists into the organization and economy of the human frame, and who would reduce their practice to a superficial imitation of form, attentively regard the Ilissus, and their doubts will be dispelled. In this statue the most consummate practical skill is made subservient to the influence of mind. With regard to the sentiment or motive of this statue, the Professor declared his opinion to be in accordance with that of the celebrated antiquary Visconti, who led the way in developing the subjects of these marbles. The Genius of so favoured a stream as the Ilissus, said to have been the resort of the Muses, must naturally have been considered as no indifferent spectator in a contest for the patronage of a country through which its waters flowed. The body of the figure is half-raised, and is slightly leaning forward, expressing his participation in the general surprise at the miracle effected by Minerva, who has just caused the olive tree to spring from the ground. The weight is supported by the left arm; the right arm is extended, and most probably, as the broken portions would seem to indicate, rested upon or fell over the knee. The head, as is evident from the position of the mastoid and the line of the trapezius muscles, was directed towards the centre of the composition.

The Ilissus presents a simple personification, the subject having no particular or palpable quality by which it could be symbolized. There is neither the elevation of Nature, as in the athlete, nor the absorption of the minor details, as in the hero, but simply the expression of the artist's individual feeling. In this statue Nature alone furnished the type; the sculptor's care was to ennoble it, and supply by sentiment the absence of attribute.

The difference, or variety of treatment of subjects of a particular class, that discriminating quality which, it has already been observed, is found to pervade all works of the Greeks, is seen, especially in the Ilissus. He is represented in the vigour of manhood. The loss of the head is indeed to be lamented, but it requires no great exercise of fancy to determine the intentions of the sculptor. The influence of mind over matter was never more powerfully illustrated than in the contracted forms of the muscles of the diaphragm, marking the effect of the drawing in of the breath; while the general meaning or intention of the figure is fully indicated by the position of the skeleton, so to speak, and the tension and rigidity of the rectus and sartorius muscles of the right thigh; affording abundant proof that the artist was well aware that expression is not confined solely to the head, but that the emotions of mind are manifested throughout the whole muscular frame.

We have several specimens of *basso relievo* of the archaic age, executed on the same principle as the Panathenaic frieze, but few have reached us of precisely the character of the metopes of the Parthenon. That compositions had been similarly applied to buildings is evident, in the examples afforded us by the discoveries made by Messrs Angell and Harris, of ancient sculptures at Selinunte in Sicily, the date of which may, with great probability, be fixed as early as 650 years B. C. The Professor then offered some observations upon the metopes of the Parthenon; first, in reference to their subjects; secondly, to their character, as applied to the building; and lastly, to their art.

Ancient art, he remarked, revolved around a living national poetry, and the mythology of the Greeks afforded abundant resources for plastic creation, and no subject could be more agreeable to, or more popular with, the Athenians, than the exploits of Theseus, under whom they had acquired the highest reputation. The metopes which have been removed from Athens, and which now exist in the British Museum, refer to the quarrel which arose between the Centaurs and the Lapithæ at the marriage of Pirithous.

The mixture, or combination, of the human figure with that of the horse was, as we learn distinctly from the description in Pausanias of the chest of Cypselus, imbodied as early as 660 years B. C. It was not, however, until the age of Phidias, that this monstrous application or configuration was conveyed under agreeable and beautiful forms; the early ages, as we find, having added to the human figure merely the hind-quarters of the horse.

It is necessary, in order to reason upon the character and relief of these marbles, to consider the site, or position rather, of the temple of which they formed the decoration. It has been supposed, not only with respect to the Parthenon, but all great temples in Greece, confined within areas, that processions were so arranged as to approach them at the angles; consequently, that a view was commanded at the same time, both of the flank and end of the building. This being the case, the necessity of considering the just balance of relief, fitted to the points of view, was obvious; and it appears, that any other relief than that

adopted in these sculptures, would have been less suitable for the purpose. Objects in lower relief would have been obscured by the projection of the triglyphs; and a higher style of relief would have broken the connexion of the triglyphs with the metopes.

From the inequality of the metopes, both in their composition and treatment, we might reasonably be led to doubt whether they were the emanations of the same mind. It is obvious they were not the productions of the same hand. In some will be found the highest qualities of the period to which they belong; in others may be traced the hard and severe style of the earlier schools; whilst others do not conform, either in sentiment, disposition, or style, with either. This may be accounted for. Phidias was an example of extraordinary genius, in advance, it may be said, of his own time; and although he retained the principles established at Ægina, and of preceding ages, he must be considered the founder, rather than the disciple, of a school. It is highly probable, also, that in the execution of the very extensive works on which he was employed, he would be compelled to call in the assistance of many artists with whom early habits and social associations would interfere to prevent their immediate adoption of his enlarged principles.

Several of the metopes offer, not only an agreeable variety in their compositions, but forcible examples of those abstract principles of representation, whether of human or brute character of form, which the Greeks sought for in nature, as immediately applicable to the distinguishing qualities they desired to imbody. Thus, in the allegorical image of the Centaur, we find in the human portion not merely a different race of men from the Lapithæ, but we see expressed the character of a people; and this, not only in the brutal and ferocious aspect of the Thessalian, but in the quality and treatment of the general forms; in the round and healthy fulness of the body, in the knotty deltoid, and in the marked connexions of the bones, approaching, in a degree, the character of the Faun, and indicative of hardy and savage habits of life. The square and compact divisions of their bodies and limbs; the truth, beauty, and education of form, and the variety of the attitudes of the Lapithæ and the Athenians, are finely opposed to the less elevated treatment of the Centaurs. The animal portion, from which the human body springs, is of the same unsubdued character, and its accordance with the human parts is finely exemplified in several of these relievi, but particularly in the victorious single Centaur, with the skin over his left arm. It is not the high-conditioned, clean-limbed Arab, which is seen in the Panathenaic frieze, but the strong-knitted, sinewy, and powerful muscle of an animal unused to restraint.

The greater part of these metopes may be considered perfect examples, as regards style; and they are equally remarkable for their execution, which is of that high quality which fully justifies us in attributing them to the hand of the greatest sculptor of the extraordinary period of Art to which they belong.

Having thus concluded his remarks on the sculptured remains of the Parthenon, as illustrative of the works of Phedias, embracing some of the finest conceptions of classic antiquity, and which must ever be regarded as a model for succeeding ages, the learned Professor proceeded, in the sequel of this lecture, to an examination of the principles on which the ancient sculptors constructed their Compositions. He said it would not be possible, in his reflections upon this subject, to separate the consideration of the mechanical from the mental or philosophical qualities or relations that are found to pervade their works. The first—the mechanical—is exhibited in the skilful disposition of the lines and balance of the masses, and in an agreeable variety in the combinations; the second, in the adoption of such forms as are consonant with the spirit in which the artist has conceived his subject; and by making the parts not only in union with each other, but subservient to a whole, conducing to that general harmony by which an impression is to be produced, or any desired effect increased.

Composition in all the arts is subject to the same general rules, though it is much more limited in Sculpture than in Painting. In this art, Composition in what is technically termed the *round*, may be classed under three distinct heads: Simple—as it applies to construction in a single object, as, for instance, in the Apollo Belvidere; Columnar—when there are two or more objects whose base is confined, or nearly parallel with its bulk, as in the groupe of Venus and Cupid in the Vatican, Bacchus and Ampelus in the British Museum, Hercules and Antæus, and the groupe of Cupid and Psyche: Pyramidal—as in the groupe of the Laocoön, Hæmon and Antigone, and the Toro Farnese. The simple may be applied in *alto* and *basso relievo*; but in this branch of sculpture, composition generally is extended to more complex disposition and arrangment, taking the oval, circular, square, or other geometrical forms, which, by well balanced combinations, may be carried to any extent; as may be seen in the Phigalian frieze, and other compositions of the kind.

A composition, whether it is simple or complex, must be true to Nature, on which all imitative art is founded. It must necessarily be governed in the balance of parts by her laws, and there is no example in the best ages of Greek sculpture in which these laws are violated. In the Belvidere Apollo, for instance, the action of the statue is carried to the greatest extent of which Nature is capable. Had the sculptor gone further, the just balance of the figure would have been destroyed, and the whole sentiment of the statue lost. Among the best examples of justly balanced, and therefore agreeably composed, Grecian statues, which do not depend upon accessories, are the Meleager, the Antinous—or, more properly, Mercury—of the Vatican, and the Jason. Among modern works, the bronze Mercury of Giovanni di Bologna, in the gallery of Florence, is pre-eminent. Independently, however, of the application of balance as a means of producing harmony in composition, there is an additional and powerful necessity for the observance of equal or just quantities in sculpture, in which a false calculation may prove fatal to a work.

The Professor remarked, that Composition, when it applies to the distribution and arrangement of matter, must be considered quite distinct from the invention which suggests that arrangement. The former is the part or work of Art: the latter has its rise in the genius of the artist; but a faculty of no mean character is required to combine or unite this matter skilfully and agreeably. The effect of the whole depending on the harmonious agreement of the forms, or a due regard to the places these should occupy, and on the absence of all restraint, they should be in unison with the action or passion intended to be represented, so that the sentiment may be conveyed in that significant and intelligible manner which will at once produce the effect required. The Greek sculptors appear to have felt strongly the great advantage to be derived from simplicity of construction, as well as from the avoidance of unnecessary and extraneous matter, in composition. It will be observed in the works of the best ages of Grecian art, that only such matter and incidents are introduced as are immediately applicable and appropriate to the subject, and all accessories which do not necessarily and essentially add to the grace, dignity, or effect of the whole are omitted. It is the multiplicity of small and unimportant parts, and the disregard of this valuable principle of simplicity, which so frequently adds to the difficulty of deciphering the subjects in many of the relievi which are found in sarcophagi of the later periods of Roman sculpture. The Roman artists followed, with respect to forms, the example of the Greeks in the filling in of the divisions of the compositions; but they appear to have overlooked, or perhaps they never understood, their principles. They outstepped the modesty of nature, and, in consequence, the complication of matter produced confusion and disorder, and instead of assisting in the illustration of the subject, the attention is disturbed and fatigued, and the eye has no point on which it can repose with satisfaction. It is at the same time very important to bear in mind that composition is not confined only to the arrangement of the great mass, but must be extended to the study of the subdivisions of that mass, and the forms those subdivisions would assume. This consideration is necessary in all extensive compositions in which much action or excitement is to be expressed. The subordinate forms in the composition which a crowd, for instance, would assume, should be in accordance with the prevailing sentiment in the mass, whether of attention or repose, or of their opposites, as of turbulence, fear, exultation, or whatever motive happens to influence it. The former—the more tranquil—would be found to act in squares, parallelograms, or other composed or simple forms. The latter, in figures of a more irregular character, as acute-angled triangles, rhomboidal or trapezoid forms. Gaiety, or the dance, would take forms of corresponding harmony.

The Professor observed, there are many works in the Academy (alluding to the collection of plaster casts) which, though they are not of a character sufficiently complete to be recommended to the students as models in the class of form, still pos-

sess qualities which, as their judgment becomes matured, might be profitably consulted on other grounds. There is, he remarked, scarcely any work of the Greeks in which there is not some peculiar and distinguishing quality to render it worthy of study and attention. The groupe of Niobe and her children is of this number, and, as an example of beauty and expression, is of the highest order. The same observation would apply to the extensive composition of figures known as Apollo and the Muses.

Apollo, in this groupe, is characterized as *Musagetes*, or the leader of the Muses, and the graceful action in the statue, and the elegant disposition of the drapery, justify the high consideration in which we may presume its prototype was held by the ancients from the numerous copies of it which are left us in marble, as also from the same figure so often recurring on coins and medals. The original statues are generally believed to have been the work of Timarchides, the Athenian. The circumstance of their being selected for the decoration of so distinguished a place as the Palace Portico of Octavia, confirms the conclusion that the statues we have are copies by Grecian sculptors, who had sought an asylum at Rome on the dismemberment of their own country.

The Olympic Games assisted in giving to the Greeks their martial spirit; but in that ardour of emulation, and love of glory, which those institutions encouraged, they were not unmindful of the milder virtues: thence the most beautiful allegory which perhaps was ever conceived, was imbodied in the Muses.

Fabled as the daughters of Jupiter and Mnemosyne, or, in other words, the offspring of Intelligence and Memory, they were presumed to preside over every art which adorned existence, or contributed to the civilization and happiness of man. They recalled the remembrance of benefits conferred; they promoted benevolence, and presented to the mind pleasing and agreeable images. The brilliant imagination of the poets gave the attributes by which they might be distinguished, themselves becoming the invokers of the divinities they had created. That beneficent luminary who received the homage of the world was, under the name and image of Phœbus or Apollo, their protector, and he was supposed to be ever present with them. Diana, or Chastity, was their constant companion, and the Graces were given them as their attendants. Apollo, in this groupe, is habited in the *palla*, his peculiar dress, as described by Tibullus and other authors when he was represented as the god of Poetry and Music. The *chlamys* is thrown negligently over his shoulder. This statue is, perhaps, the most elegant in the whole series. The *motivo*, or intention, expressed by the action, is that of heavenly inspiration. The drapery is broad, and on a beautiful principle, and all the minor divisions are nicely adapted to display the form. It will be observed, that the Greeks, in all clothed statues, were attentive to the general divisions of the figure; even the chest was indicated, the hip decidedly defined, and one or both knees, whenever possible, were marked; and so carefully was this principle observed, that there is not a Grecian statue in existence in which, however fully it may be dressed, the forms and action, or, in other words, the intention of the figure, may not be discovered.

Of the statues of the Muses in this groupe, the most distinguished in the class of composition to which they more immediately belong, are Euterpe, Thalia, Melpomene, Erato, and Polyhymnia.

There is no statue in this collection which we contemplate with greater regret for the loss of the original, or which excites a stronger desire that its prototype may yet be restored to us, than that of Melpomene. The action is imposing and characteristic of the Muse; and, notwithstanding its great faults, the air of majesty and grace, of noble and profound melancholy, which pervades it, moves us sensibly on beholding it. There is a mixture of sternness, and yet of fascinating beauty, in the head of this statue, and a grace through the whole *busto*, which are peculiarly striking; and the rich and full masses of the hair, picturesquely combined with the Bacchic wreath of vine-leaves and fruit, render it altogether one of the most enchanting productions transmitted to us of ancient Art.

There is a coarseness of execution throughout the whole of these statues by no means in accordance with the composition or the sentiment which pervades them. This is one of the many reasons for believing them to be copies by inferior artists. It is not improbable that, with accessories at the termination, they may originally have occupied the pediment of a building. These statues are also excellent examples of simple composition, as it applies to action or construction in a single object. The Professor closed some remarks he had made on the judgment shown by the Greeks in their choice of momentary action, and harmonious combination of invention and composition, by some observations on the Belvidere Apollo.

This statue, he said, may justly be considered an intellectual work; it is the finest model in existence of the sublime in what is termed Ideal Art. The mind of its great artist appears to have been raised to that conception of character which was not only appropriate to a god, but to the god of eternal youth and beauty. It is the union of all that is beautiful in thought, rendered visible through matter, without the grossness of materiality. The head supplies a fine example of judgment in the preservation of character without the slightest violation of beauty. The scorn expressed in the inflation of the nostrils; the contempt in the lower lip; and pride in the brows, are so regulated by the grand and open simplicity of the forehead, that we find nothing derogating from the dignity of the god. Self-possession and tranquillity reign throughout the whole. The head of the Apollo conveys more instruction than any other in existence, and he who is fully acquainted with, and capable of producing an exact imitation of that head, (and the same may be said of the feet, as regards these extremities,) may say he is thoroughly grounded in the grammar of his Art.

In Columnar composition, or that class of arrangement which includes two or more objects, whose base is confined, or nearly parallel with its bulk, a very pleasing example may be seen in the groupe of Cupid and Psyche. There are few compositions which, for the interlacing of lines and harmony of the parts, are more agreeable to the eye. Pyramidal composition assumes, in a great degree, a different character from the preceding classes, in not requiring so strict an adherence to the balances of the angles, such compositions being often intended for particular situations, and, consequently, limited points of view. The best exemplification of this class of composition, is the marble groupe of Laocoön and his sons.

This group supports the observations already made, that the general form of a composition should be agreeable to, or consonant with, the prevailing sentiment in the subject. It is so with the groupe of Laocoön; a mere blot of the composition would be indicative of excitement, and of a perturbed subject.

Alto and Basso Relievo differ much in the principle and character of their composition from the classes hitherto considered, in which, the object being to produce an immediate effect, there was a necessity for compression.

In alto and basso relievo which, both from surface and extent, approaches more nearly than any other branch of Sculpture to the sister art, there is always less necessity for this compression. Assuming the character of a narrative, it admits of all such simultaneous incidents as belong to the subject; and this enables the sculptor to diversify his work; for where the incidents are judiciously contrasted, the variety not only heightens the effect of each, but renders the whole agreeable to the eye.

In considering the compositions of the Greeks as they apply to alto or basso relievo, and especially in compound or complex arrangements, their combinations will be found so constructed and balanced, that even by transposition the connexion or mutual harmony is not affected. A valuable illustration of this is afforded in a well-known alto relievo of Niobe and her Children, which forms the subject of the front of a sarcophagus in the collection of sculpture in the Vatican. This work is of a late age, and is rude in its execution, but the invention, expression, and other high qualities that are found in it, prove it to be the production of a very superior mind.

This composition is a perfect whole, and yet the parts of which the whole is composed, are also perfect in themselves, and they maintain their place without affecting other parts, but are capable again of admitting their combinations.

Speaking of the merely mechanical qualities of composition, the Professor took occasion to observe that an artist may be a tolerable composer, without possessing, in any great degree, the faculty of invention. But he begged the students to bear in mind, that it is in proportion only to the degree of power with which the inventive faculty is exercised, that a composition affects the spectator.

Very good examples of merely mechanical arrangements may be seen in many of the sarcophagi of the later periods of Roman Art, more especially in those of the age of Commodus.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXVI.

OF VISION (CONTINUED).—SECTION III.: PHYSIOLOGY AND DISEASES OF THE EYE.

The adaptation of the eye to the perception of the external world, by means of colours, is a fact which has been much enlarged upon by many philosophic and popular writers, and consequently need not be here dwelt on. The human eye may be said to be an extremely perfect organ, without claiming for it any exaggerated powers. There are animals superior, no doubt, to men in their powers of vision, as the eagle, and especially the vulture; whilst even amongst men it is not in the most gifted races that we find the strongest range of vision. In this respect, the eye of the negro, but more especially of the Hottentot and Bosjesmen of Southern Africa, far excel the European and, probably, all other races of men.

The essence of the organ of vision, wherever found, consists in "a series of transparent media being placed in front of a special apparatus;" that is, of an expansion of a portion of the nervous system having interposed between it and the external world a series of transparent media, each possessing powers of refraction, and otherwise modifying the rays of light proceeding from luminous bodies through these media, until they impinge or affect the retina, that is, the sensitive organ, for the sake of which all the other parts were formed. Even in the leech and in the sea-worm there is a pupil admitting the rays of light into the interior of the eye. Something analogous to the lens and vitrine follow this, or are placed behind it, refracting the rays of light to the requisite extent, and no doubt causing them to meet in a focus upon the nervous points, or fibrillæ, which are placed in the back of the organ. The evil effects which flow from an opacity of the cornea or of the lens in man, unhappily illustrate too well the necessity for the transparency of the media between the retina and the external world; deep opacities of the cornea render the organ useless by impeding or arresting the progress of the rays of light in their course towards the retina. Some ingenious attempts have lately been made to remove the opaque cornea, and replace it by a healthy transparent one taken from the eye of another animal, but it is extremely unlikely that such experiments will ever succeed on the human eye.

The surface of the eye-ball in the young and healthy has a peculiar lustre, which it loses so soon as the frame suffers from debility, exhaustion, or distress of mind. The lustre may either be simply healthy and natural, or morbidly exalted, as in passion and during the accession of intense fever; and in mania and delirium, however induced. The immediate cause of the lustre of the healthy eye is probably the action of the muscles of the eye-ball maintaining it firmly in its place, pressing it against the fatty cushion against which it rests, and giving to it, in short, that tension necessary to render the cornea prominent, clear, and full. In general, as life ceases the lustre departs, although there are exceptions to this, which it would not be difficult to explain. As life ceases all the muscles of the body lose a part at least of their general tone, and so also do those within the orbit. A curious fact having reference to this was first noticed by the late Dr. John Barclay. As he was preparing by dissection some sheep's eyes for demonstration to his class, he accidentally squeezed one of them firmly in his hand; as the pressure continued, the cornea became at first bluish, and afterwards more and more opaque, until it seemed to have lost altogether its admirable quality of perfect transparency. On relaxing the pressure, the cornea recovered its transparency. The cause of this has never been explained; but as it is a fact, that the cornea loses something of its transparency by strong pressure exercised on the eye-ball, the circumstance may perhaps explain the confused and indistinct vision of persons labouring under the delirium of passion, in whom the muscles of the whole frame become violently agitated, a condition extending no doubt to those within the orbit. But indistinctness of vision does no doubt arise in those who are passionate or mentally disturbed from another cause, which we shall shortly explain.

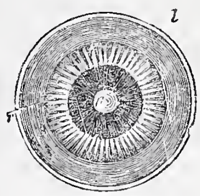
The human eyes then, like those of all other animals, possess in health an admirable lustre, though they never glare like those of the lower animals. All that the poets have written about this is, as usual, mere nonsense and contrary to truth, to which they in general pay no respect. But there are phenomena to which they have attended, which, being more in accordance with physiological laws, may here be noticed.

A person intoxicated, or in a phrenzy of passion, or agitated with fear and in deep terror, sees objects double; that is, he has lost for the time the power of directing aright the axes of both eyes towards one object; hence there may be more literal truth in the remark than at first appears,

"Fear doubled his enemies."

Adverting now to the uses of the various parts of the eye, we may mention first the aqueous humour. It is to it that the cornea owes its fullness, and when this is punctured the humour escapes very readily. It is as readily restored, however, by the ordinary powers of the animal economy. Of the iris we have already spoken. In the eyes of the Saxon race it is of a blue or grey colour; in the negro, quite dark, thus partaking of the general system of coloration of the whole body. Letters have been fantastically read on it by heated imaginators. Its most remarkable, and as yet inexplicable faculty, is that of so narrowing and expanding as to alter the dimensions of the circular aperture found in its centre (the pupil), thus admitting more or less fully into the interior of the eye the rays of light. This admirable and wonderful faculty in the iris was known to Aristotle. It could not indeed have escaped the notice of any observing person. Moreover, if a person be desired to look at a very near object, and the movements of the iris be watched, it will be seen to contract almost to a point until, the effort becoming painful, it suddenly relaxes, and the pupil is restored to its former average dimensions. If he be then desired to look at a distant object, the pupil may be seen to dilate. These movements do not imply, however, that we have any real voluntary control over the motions of the iris, although the parrot is said to possess this; and the same may be said, I think, of the cat, lion, and tiger. To explain these movements, physiologists have been forced to presume the existence of certain structures in the iris which have not been fully proved; namely, radiating muscular fibres, and a sphincter muscle; as thus:

Fig. 5.



A view of the interior surface of the iris.

b, The base by which it is fixed to the choroid tunic and annulus albus; *p*, the pupil; *r*, the radiating fibres; *s*, the sphincter.

Upon the whole, however, physiologists are agreed that it serves at least the same purpose as the diaphgram placed in the optical instruments to correct or prevent the indistinctness of vision arising from the spherical aberration of the lenses.

The iris abounds with blood-vessels, and especially with nerves, and more especially in animals of quick and rapid vision, as in birds, antelopes, deer, &c.; in man also the iris is well supplied with nerves. These movements of the iris would seem, in a certain degree, to be connected with a singularly beautiful power the eye possesses of adapt-

ing itself, with more or less rapidity, to the distinct perception of objects more or less remote. We shall consider this faculty when speaking of the annulus albus, or ciliary ligament.

Of the refracting media placed within the eye-ball, the lens is admitted to be the most important; it serves, in fact, the purpose of a magnifying glass or lens of very great powers placed within the eye. It presents within the eyes of various animals a great variety of forms, being perfectly globular in some, as in fishes; and in man and in birds, biconvex. This form seems best adapted for an extended range of vision. The lens of the cod and haddock when quite fresh may be used as a magnifying glass; and it may probably be owing to this globular form of the lens in fishes, that some of them at least see animals in the waters which are perfectly microscopic to man. This is the case with the verduce of Loch Maben, which lives exclusively on microscopic entomostracea, or shell fish, so small as to be invisible to the unaided human eye. The herring lives chiefly on the same food; the char also, and at certain seasons of the year, one kind at least of the Lochleven trout. Other aquatic animals, besides fishes, have the lens of a globular form; and this property extends also to the more common quadrupeds, and is not peculiar to them.

The lens is said to be without structure, and without blood-vessels or nerves; in this respect, therefore, it is an excretion, and has been compared to the hair, nails, and teeth. It is certainly quite free in its capsule, which contains besides a small quantity of liquid termed the liquor of Morgagni. In this liquid of Morgagni recent observers have noticed some singular spindle-shaped bodies. The surface of the lens is soft and cellular, but underneath this it is fibrous and laminated like an onion, and is moreover said to possess an arrangement of matter which no art has yet been able to approach; namely, a progressively increasing refringent power by a density progressively increasing from the circumference to the centre; such an arrangement no doubt contributes to correct in the human eye that phenomenon called irization, found to exist in certain telescopes.

It has occurred to me to observe many peculiarities in vision, which, though noticed merely in individuals, may yet characterize numerous classes. I have known persons of the very finest and most acute sight who could not employ or use a common botanical lens or magnifying glass; their sight did not seem to require it. Moreover, it is a great mistake to suppose that what one person sees readily should be as readily seen by others possessing sound vision. The eye must be exercised, and many who have not previously seen the object can with great difficulty be instructed how to look for it. A few years ago Sir John Herschell discovered with the aid of a microscope of high powers an arrangement of matter hitherto unobserved; he published the fact, but although carefully looked for, some of the first observers in the kingdom failed in rediscovering it. At a meeting with Sir John Herschell, Sir D. Brewster mentioned the circumstance, when, with a slight modification not attended to by them, the structure in question was made manifest to all.

A remarkable proof of the difficulty of pointing out even to the acutest sighted of men an object which they have *never seen before*, or which, from its *magnitude*, or *form*, or *colour*, or diminutive size, is altogether different from their preconceived notions, occurred to the author whilst residing on the frontiers of the colony of the Cape. After the expulsion of the Amokoss Caffre race from the territory watered by the Koonap, Kat, and Keiskenne rivers, by the British in 1820, it was deemed advisable by the colonial government to declare the territory for the future a "Neutral Territory," which was not to be occupied nor encroached on permanently by either race, British or Caffre. Into this tract of country the "wilde," or game and wild beasts as we term them, rapidly returned: the absence of man, the agreed enemy and chief destroyer, offering them every security. Into this territory as a precautionary measure, "patroles" of small parties of armed men were sent by the British; small detachments, in fact, from the regiments stationed on the frontiers. One of these, consisting of fourteen men and commanded by Ensign C., I accompanied, my principal object being to ascertain the precise junction of the Koonap and Kat rivers, a spot which, so far as I could learn, had never been visited by any European. Now, it happened that neither Ensign C. nor any of his party had seen an elephant, a circumstance which was incomprehensible to me, seeing that they had frequently patrolled over a district which I knew to abound not only with elephants, but with every sort of "*wilde*." Accordingly I promised him that before the close of the third day (the limit of our patrol) I would most certainly be able to point out to him a drove or two of those wondrous animals, for I knew that they visited that district in droves of three or four hundred at a time. Our first day's route lay along the high lands connected with the course of the Koonap river, which the elephants had for the time seemingly abandoned, as none were met with; but on the forenoon of the second day, having crossed the Koonap, and as we marched towards the point I was desirous of examining, namely, the junction of the Kat and Koonap rivers, I discovered at the distance of about a couple of miles a drove of elephants of at least three hundred in number. A grassy plain, on which grew a few scattered mimosas, lay between the parts and the wooded hill, on the northern slope of which, scattered over its whole surface, grazed the majestic animals we were in search of. The hill was a portion of a range of hills dividing the territory we were now in from the wild, desolate, and unprofitable district of the Great Fish river; it was, like the others, not covered with forest trees, (for there are, properly speaking, no forest trees here,) but with tall bushes, some of them fifteen or twenty feet high, and only partially covering the sides of the hill, the brown clay soil appearing at intervals. I mention these circumstances as they tend to explain the singular occurrence which next took place. The instant I saw the side of the hill it was easy for me, the appearance being quite familiar, to distinguish hundreds of elephants quietly browsing on the tall bushes covering its surface, and I pointed them out to Ensign C. and his party; but although they gazed at the hill and at the elephants which I distinguished so clearly, none of the party could discern a single animal. It was in vain that I pointed out to them the enormous living masses moving among the bushes, which at times their carcases obscured, and by which they were at times lost to view; the movements of the proboscis, the gambols of the young, were all distinctly visible to the experienced eye—to the military party they were perfectly invisible. Baffled in my efforts to enable the party to discover the drove, Ensign C. and myself (the only persons of the escort who were on horseback) rode gently forward towards the base of the hill, across the open grassy plain, when, coming within about a mile, the whole drove became at once visible to him, and he stood astonished; first at the sight, and afterwards at the difficulty he had experienced in discovering objects of such magnitude; whenever indeed the precise outline of one elephant was clearly made out, all the rest became apparent; the difficulty seemed to be, *the clearly perceiving one*. As far as I can recollect, none of the party we left on the verge of the plain made them out.

Another observation, something similar in character, is a seeming narrowness of mental and bodily vision, disabling the person from grasping at one view all the details of an object presented to him. The result is, that the whole is unintelligible, by reason that he sees it only in detail. Many remarkable instances of this deficiency once occurred during the exhibition of the great northern whale in the exhibition rooms of the Royal Institution in Edinburgh—numerous highly educated persons were found altogether unequal to the making out of the form of the skeleton, as exhibited, although to others of a wide verge of mental and bodily vision nothing was more distinct. It would be difficult to say how this arises; with some it might be owing to their preconceived notions of the relative bulk of individual parts having had so strong hold of their minds as to disqualify them from conceiving or of perceiving in nature forms so different from those with which they were familiar.

Another peculiarity in the vision of different persons is the power of rapidly adapting the eye to various distances. This is essential to the sportsman, to the observer, to the engineer

in short, to all men who pretend to be observers. The seat or cause of this faculty, which the eye possesses, has never yet been well explained: some ascribing it mainly to the iris: others to the external muscles surrounding the eye-ball: and others to a peculiar ring or circle called the *annulus albus*, whose position is near the junction of the cornea and the sclerotic tunic. On whatever this function of the eye depends, certain it is that all men possess it, but in very limited degrees; mere children, for example, have it in a very inferior degree, whilst in some military men, with the very best vision, it is so slowly increased as to be of no use to them in the field. I well remember an officer whose sight was remarkably powerful, and who could, once the object was fairly seen by him, make out all its details at incredible distances; but the difficulty always was, to get him "*to see the object*": once seen, he saw it better than any of us. On this principle I feel disposed to explain how it is that many persons will travel over strange lands and *see nothing*; I rode once, with another officer, through a lovely valley full of game; in half an hour I counted at least 40 head of game, from the rhinoceros to the partridge; my friend returned exactly as he went—he had *seen nothing*. Caille, who says he travelled from the mouth of the Gambia to Timbuctoo, and never saw a wild animal, must have resembled my friend in this respect.

The Retina (see Plate) or the expansion of the optic nerve, as some are pleased to consider it, is the most difficult to examine of all the structures, and the least understood. The Germans point out arrangements in its ultimate form, which have not been confirmed in this country. The membrane, which is a complex, and not a simple one, is still presumed to be the immediate instrument of vision, and to form the harder surface upon which is depicted the image of all external bodies seen by us. These views are quite hypothetical, and are rendered even improbable by the fact that, in the *axis of vision*, where alone we perceive and see distinctly, the *pulpy or nervous retina* is wanting; there is, in fact, a hole in the membrane at the point where we see best; *where* the optic nerve enters is the *punctum non videns*, or point at which we do not see. The range of distinct perception is extremely limited; of this truth any one may satisfy himself by endeavouring to count the books on a shelf, when he will find that he cannot count more than one properly or two at most without continually shifting the axis of vision.

The choroid tunic is the vascular and varnishing membrane of the eye; it converts the eye into a camera obscura. The sclerotic is the protecting fibrous membrane; the uses of the other parts of the eye have been already referred to. Both eyes are required to decide with due precision on the distance of any very near object, although it seldom happens that both eyes have equal power; nay, in numbers of persons one eye is found to be altogether or nearly useless, although this could not be surmised from any external appearance.

The theory and history of the subjective phenomena of the organs of vision, viz., apparitions, phantoms and spectres, has been so fully and so ably treated of by Dr. Hibbert, Sir D. Brewster, and others, that any remarks here might appear out of place, or at least superfluous. With a few further remarks then we shall close this section.

1st, There is a harmony in colours, exemplified by what we see in the dresses of various nations placed under different circumstances, as to light and shade; nothing, for example, looks worse in our cold, cheerless, cloudy country, with its china ink skies, than the gaudy dress of the oriental races, their white and yellow robes, their bright colours, their gaudy tinsel ornaments. On the other hand, an Englishman with his duffle and drab or black coat, and brown waistcoat, is the most ludicrous looking animal in the world under the Persian or the African sun.

2d, Wagner, one of the latest writers on Physiology, thinks that even yet no true theory has been offered of the curious fact that, whilst all the objects of the material world are painted, or represented on the retina of the eye in an inverted position, we still see them correctly, and not inverted but upright. Many years ago an explanation of this singular fact was offered by Mr. Alexander, Walker a most distinguished anatomist and physiologist; his explanation rested on the fact, that the fibres proceeding from the retina to the brain are inverted in their course, that is, those proceeding from the lower parts of the retina reach the upper part of the brain, and *vice versa*; this, of course, produces an inversion of the ideas.

DISEASES OF THE EYE.

The eye, as may be supposed from the complexity of its structure and uses, is liable to many diseases.

Sometimes the optic nerve, or retina, is palsied, and the disease called amaurosis, or, more familiarly, gutta serena, is produced. At other times the transparency of some of the refracting media is destroyed, and the rays of light thereby prevented from impinging upon the retina. Such constitute the affections of cataract and glaucoma.

Both the lens and its capsule are liable to opacity, which more or less impedes vision, and constitutes the disease called cataract. The lens, when thus affected, is sometimes softer, and at others harder, than natural, and hence the systematic writers describe a hard, soft, and milky cataract.

The causes of cataract are very obscure. One of the predisposing causes of it is old age, and the tendency to it seems to be hereditary. The exciting cause is sometimes a blow upon the eye, but is as often not appreciable.

Cataract may be known by two positive and one negative symptom. First, the pupil, instead of being black, is brown, yellow, or white. Secondly, the vision is defective, and there is sometimes complete blindness, except that the power remains of discerning the outlines of objects held between the eye and the light. Thirdly, the iris is moveable.

In general, cataract comes on gradually, the opacity, and, consequently, dimness increasing by slow degrees. During this progress, the patient always sees best in an obscure light, because in such the pupil dilates most, and exposes the lens towards the circumference, where the opacity is always least.

The only cure for cataract is a surgical operation, and three methods of thus treating it are in use. One of these is called couching, and consists in putting a needle into the eye, and pushing down the opaque lens. Another consists in cutting out the lens altogether; and the third consists in introducing a needle, and breaking up the lens into bits, which are subsequently absorbed.

The best mode of treatment is held to be, in general, to introduce a curved needle through the sclerotic, and depress the lens, if found to be firm, and to break it up, if soft.

After the operation, the patient requires to be confined for some days to a darkened room, and observe an antiphlogistic regimen.

With reference to glaucoma, a similar affection, Cooper observes, that in this disease the eye is green or yellowish-green, and if the eye be looked at laterally, no discoloration is seen. In cataract, the pupil is grey or greyish-white, and it has the same appearance in whatever direction it is viewed. In glaucoma, the loss of vision is not in direct proportion to the change of colour in the pupil. With an inconsiderable change, vision may be entirely destroyed, or seriously impared; but in cataract, there is a direct proportion between the degree of opacity, and the injury to sight. In cataract, vision is best in a weak light; in glaucoma, it is stronger in a powerful light, because, as the retina is less sensible, more light is required to make an impression on it."

Almost all the tunics and other parts of the eye are liable to inflammation; the conjunctiva is more particularly so; and in this the inflammation may be set up by exposure to bright light, intense heat, cold winds, dust, and foreign bodies, and also by disorders of the stomach. Moreover, when the conjunctiva has been once inflamed, the inflammation is very apt, from slight causes, to recur. This inflammation is sometimes very acute, and at others quite chronic. In the acute forms, there is great redness and injection of the affected membrane, swelling of the eyelids, and great secretion of tears, intolerance of light, pain in the eye, with the sensation of sand in it, and symptomatic fever. This latter is absent in the chronic form,

and in such the other symptoms are far less urgent. In treating inflammation of the conjunctiva, it is, above all, necessary to protect the eye from all sources of irritation. This is best done by darkening the room, and keeping the eye constantly covered with linen cloths, dipped in evaporating lotions, and changed from time to time, or with bread-and-milk poultices. If the fever be great, bleeding is proper; and in acute cases, the application of leeches in the neighbourhood of the inflamed organ is always advisable, and saline purgatives should be administered.

Nebula (see Plate II., fig. 4) is the name given to an effusion of lymph between the conjunctiva and the cornea, caused by inflammation. It produces, of course, more or less opacity. It is best treated by the application of opium, wine, or solution of nitrate of silver.

Pterigium is the name of a reddish preternatural membrane that sometimes begins to grow at the internal angle of the eye, and, gradually extending, at last obstructs the cornea. It is represented in Plate II., fig. 6. It is an occasional result of inflammation of the conjunctiva, and is most prevalent in warm climates: stimulating lotions may be applied to it, and these failing, it must be cut away.

The cyelids are liable to two or three somewhat peculiar affections. The most important of these are:—

1. The *Stye*, which is a small abscess that almost invariably goes on to suppuration. It is best treated by fomentations. When it has once come on in an individual, it is very liable to recur.

2. *Ectropium.*—This, as shown in Plate II., fig. 7, consists in a turning out of the eyelids, generally in consequence of the attacks of ophthalmia, or inflammation of the eye. It is a distressing affection, being generally accompanied by continual discharge of tears and inflammation of the conjunctiva, and sometimes by ulceration of the cornea. Application of lunar caustic to the inflamed edges is often beneficial. The appearance of the eye, when cured of this affection, is shown in fig. 8. The reverse of Ectropium is—

3. *Entropium*, or a turning in of the eyelids. The cure of this requires a surgical operation.

PRINCIPALS OF ALGEBRA.

CHAPTER VIII.

ALGEBRAICAL SYMBOLS.

72. We have hitherto regarded the symbols + and — as denoting simply addition and subtraction, and *zero* as the absolute *minimum* of all quantity. Thus far, therefore, our operations have been purely arithmetical; but we pass now to modifications in the meaning of our symbols, which have no direct parallel in arithmetic.

73. To express the difference of a and b, we write $a-b$. In an arithmetical sense, this difference is without meaning if b be greater than a, In this sense, we are therefore compelled to consider a and b as limited in relative magnitude, when placed in such circumstances with respect to each other; but as these symbols are general in their character, it becomes necessary to generalize the expression denoted by —, so that it may admit of application co-extensive with the symbolical quantities which it connects. Such an extension is deducible immediately from our rules: for,

1° Let a be *greater* than b by the quantity c; that is, let $a=b+c$ then $a-b=b-b+c$ which is $+c$.

2° Let a be *less* than b by the quantity c; that is, let $a=b-c$; then $a-b=b-b-c$ which is $-c$.

As these results, $+c$ and $-c$, are obtained by following established rules, they must admit of interpretations in conformity with the principles on which these rules are founded, The first consideration is this: + and —, when used to connect quantities which allow of combination, denote inverse operations; if, therefore, we would simply *extend* their meaning, so as to render them expressive of the qualities of isolated quantities, the properties assigned to them in this capacity must bear a similar relation.

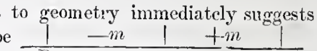
This relation is expressed when + prefixed to an insulated quantity is made to affect that quantity in a contrary way to — similarly prefixed; that is, when $+c$ and $-c$ are taken to express exactly opposite meanings of the same quantity c, as *profit* and *loss*.

74. *Definition.* When + and — are prefixed to insulated quantities, they are called signs of *relation* or *affection*; whereas, when they serve to combine quantities, they are called signs of *operation*. Moreover a quantity, whether combined or insulated, having the sign — prefixed, is said to be *negative*,

As there are but these two alternatives: either a quantity must be affected by the sign + or the sign —, it is agreed when no sign is used, to consider + as the sign affecting the quantity. c is therefore to be taken in the same sense as $+c$, and *vice versa*.

75. The following is then the meaning which we are to attach to algebraical quantities in relation to their signs: *They are either positive or negative according as they are affected by the sign + or —; the signs + and — give to quantities directly opposite significations*, e. g. *if* +m *mean a gain of* £m, *then* —m *will mean a loss of the same amount; if* +m *mean a loss of* £m, *then* —m *will mean a gain of the same; if* +m *mean* m *years before, then* —m *will mean* m *years after; if* +m *mean* m *degrees of south latitude, then* —m *will signify the same number of degrees of north latitude, and so on.*

The application of algebra to geometry immediately suggests this species of extension. If A be a point in a straight line, indefinitely extended both ways,



and if any quantity AB_1 measured towards the right of A be called $+m$, then the same distance AB_2 measured towards the left of A will be represented by $-m$. In the same way, the terms *height* and *depth*, *ascent* and *descent*, *above* and *below*, *backwards* and *forwards*, *before* and *after*, *heat* and *cold*, *property* and *debt*, involve in common the notion of opposite directions, and are consequently all symbolized by the signs + and — applied to the symbols denoting their magnitudes.

76. Addition and Subtraction. The first of these terms means the uniting of two expressions into one without altering the signs of either; and the second, the uniting of two expressions into one by changing all the signs of that which is said to be subtracted. The following examples will show that these significations are consistent with the generalized meanings given to + and —.

Quantities given.	By the rule.	Admissible forms.		Results.
To a add $+b$	$a+(+b)$	$a+(0+b)$	$a+(b+0)$	$a+b$
To a add $-b$	$a+(-b)$	$a+(0-b)$	$a-(b-0)$	$a-b$
From a take $+b$	$a-(+b)$	$a-(0+b)$	$a-(b+0)$	$a-b$
From a take $-b$	$a-(-b)$	$a-(0-b)$	$a+(b-0)$	$a+b$

Let it be here carefully observed, that wherever two *like signs* come together in the operation, the corresponding part in the result has the sign +, and wherever two *unlike signs* come together, the corresponding part in the result has the sign —.

$\therefore a+(+b)$ may be written for $a-(-b)$ but the correct form is $a+b$

$\therefore a+(-b)$ . . $a-(+b)$. , . $a-b$

For Exercise. Show that the following equations are identical.

$$a+m-\Big(n-(m-n)+p\Big)=a+2m-2n-p$$

$$a-\Big\{a+(n-b+c)-2\Big(a-m-(n-b)\Big)\Big\}=2(a-m)+3(b-n)-c$$

$$1-\Big\{x-\Big(y-z-(x-1-(x-y))\Big)\Big\}=2-(x+z)$$

$$-m-\Big\{n-m\Big(n-p(q-1)-1\Big)-m-n\Big\}=m\Big(n-1+(1-q)\Big)$$

Let the effect of an *even* and an *odd* number of like signs be carefully observed in the following and similar formulæ.

$$-\Big\{-\Big(-(-x)\Big)\Big\}=+x \qquad +\Big\{+\Big(+(+x)\Big)\Big\}=+x$$

$$+\Big\{-\Big(-(-x)\Big)\Big\}=-x \qquad -\Big\{+\Big(+(+x)\Big)\Big\}=-x$$

$$+\Big\{+\Big(-(-x)\Big)\Big\}=+x \qquad -\Big\{-\Big(+(+x)\Big)\Big\}=+x$$

77. *Greater and Less.* These terms are symbolised by + and —, in their ordinary arithmetical signification of addition and subtraction; but the extension of the meaning of our symbols requires a corresponding extension of the meaning of the terms which they are made to represent.

Let the numbers, 1, 2, 3, &c., be successively subtracted from P: The process is as follows—

P—1 P—2 P—3 P—4 P—5 P—6 P—7 P—8 P—9

Let now P = 5, and let the subtractions be actually performed, algebraically: we get

$$+4 \quad +3 \quad +2 \quad +1 \quad 0 \quad -1 \quad -2 \quad -3 \quad -4$$

a series of remainders which continually decreases towards the right *(for the greater the quantity subtracted, the less must be the result)*, and in which *zero* appears as the *common limit* of the *positive* and *negative* terms. The *maximum* and *minimum* of algebraical quantity are therefore equally unlimited. From the same series it further appears,

1°. *Comparing any two positive quantities, that is the greater which is arithmetically the greater; comparing two negative quantities, that is the greater which is arithmetically the less.*

Thus: $+2$ is greater than $+1$, and -1 is greater than -2.

2°. *Any positive quantity is greater than zero; any negative quantity is less than zero, or requires a positive quantity of equal arithmetical magnitude to be added to it, to give a result equal to zero.*

Thus:

$+1$ is greater than 0, and -1 is less than 0, for $-1+1=0$

78. The following propositions will now be understood.

I. Addition of $\left\{\begin{matrix}\textit{positive}\\ \textit{negative}\end{matrix}\right\}$ quantity causes $\left\{\begin{matrix}\textit{increase}\\ \textit{decrease}\end{matrix}\right.$

For example: The sum of $+5$ and $+4$ is $+9$, but the sum of $+5$ and -4 is $+1$.

The sum of -5 and $+4$ is -1, but the sum of -5 and -4 is -9

II. Subtraction of $\left\{\begin{matrix}\textit{positive}\\ \textit{negative}\end{matrix}\right\}$ quantity causes $\left\{\begin{matrix}\textit{decrease}\\ \textit{increase}\end{matrix}\right.$

For example:

The difference of $+5$ and $+4$ is $+5-(+4)=+1$
The difference of $+5$ and -4 is $+5-(-4)=+9$

III.* Adding $\left\{\begin{matrix}\textit{positive}\\ \textit{negative}\end{matrix}\right\}$ quantity is equivalent to subtracting $\left\{\begin{matrix}\textit{negative}\\ \textit{positive}\end{matrix}\right\}$ quantity.

For example: $+5+(+4)$ is equivalent $+5-(-4)$ which is $+9$
$+5+(-4)$ . . . . $+5-(+4)$ . . $+1$

79. *Definition.* To denote that one quantity is greater or less than another, they are written consecutively with the sign $>$ between them in one case, and $\angle$ in the other, thus:

For a is greater than b, write $a > b$

For a is less than b, write $a \angle b$

Exercises: Do the operations required in the following table, and prove the results.

To	Add	Sum
$-(a-b)$	$+(b-a)$	$2(b-a)$
$-(a-b)$	$-(b-a)$	0
$-(-(-a))$	$-(+(-b))$	$b-a$
$5a$	$-(3a-(2a-1))$	$4a-1$

From	Subtract	Remain
$x-(+a)$	$a-(-x)$	$-2a$
$a-(a+b)$	$-(b-a)$	$-a$
$-(1-a$	$-(1+a)$	$+2a$
$a+b$	$-(b+(a-b))$	$2a+b$

80. Multiplication and Division. These rules are (by *definition*) in all respects the inverse of each other, and for ascertained quantities are the same in arithmetic; but the law by which isolated quantities, affected by the signs $+$ and $-$, are incorporated when brought together by the operations denoted by $\times$ and $\div$, requires still to be considered. We are therefore to show that the language of the signs is such that

I. *In Multiplication* $\left\{\begin{matrix}(+a)\times(+b) \text{ and } (-a)\times(-b) \text{ give } +ab\\ (+a)\times(-b) \text{ and } (-a)\times(+b) \text{ give } -ab\end{matrix}\right.$

Let there be the equation $m-n=p-q$ in which $m>n$ and $p>q$; and let $a=b$; then will $+a=+b$ and $-a=-b$. If now we multiply $m-n$ by $+a$ and $-a$, and $p-q$ by $+b$ and $-b$, and make the products of the *like* signs $+$, and the products of the *unlike* signs $-$, we get

$$+am-an=+bp-bq \qquad -am+an=-bp+bq$$

which we know to be true equations. The rule for the multiplication of the signs may therefore be made general.*

II. *In Division.* $\left\{\begin{matrix}+ab\div(+b)=+a, \text{ because } +b\times(+a)=+ab\\ +ab\div(-b)=-a, \text{ because } -b\times(-a)=+ab\\ -ab\div(+b)=-a, \text{ because } +b\times(-a)=-ab\\ -ab\div(-b)=+a, \text{ because } -b\times(+a)=-ab\end{matrix}\right.$

which results shew that the rule of signs is also applicable in division.

81. From the preceding and similar considerations we derive this

Rule. *When in any operation two like signs are brought together, whether $+$ and $+$, or $-$ and $-$, they are replaced by the single sign $+$; but if the signs are unlike, whether $+$ and $-$, or $-$ and $+$, they are replaced by the sign $-$. (The sign $+$ is understood, when no sign is prefixed.)*

For Exercise. The following instances will render this rule familiar in its relations to multiplication and division.

Multiply	By	Product.
$\times\ 3a-1$	$+7ab$	$21aab-7ab$
$+2x$	$-ay$	$-2axy$
$-x+y$	$+an$	$-anx+any$
$-\frac{1}{2}a+\frac{1}{4}b$	$-4xy$	$2axy-bxy$
$3a\times-4ab$	$-5abc\times 6a$	$360aaaabbc$
$\frac{ba}{2xx}\times-\frac{ax}{by}$	$-\frac{bbxy}{ccz}$	$+\frac{aabb}{2ccx}$

It is left to the ingenuity of the student to reverse the operations of the preceding and following tables.

Divide	By	Quotient.
$-12abcde$	$-8acd$	$\frac{3}{2}bc$
$-24aaabb$	$8aabbx$	$-\frac{3a}{x}$
$xy-8x$	$-4x$	$-\frac{1}{4}y+2$
$+3aab-y$	$-aby$	$-\frac{3a}{y}+\frac{1}{ab}$
$m+(1-v)$	$-(v-1)$	$1-\frac{m}{v-1}$

82. *Proposition.* A product is not affected by changing the signs of the *multiplicand* and *multiplier*, nor a *quotient* by changing the signs of the *dividend* and *divisor*: for

$+ab$ is both $+a\times+b$ and $-a\times-b$
$-ab$ is both $-a\times+b$ and $-a\times-b$

$$+\frac{a}{b} \text{ is both } \frac{+a}{+b} \text{ and } \frac{-a}{-b}$$

$$-\frac{a}{b} \text{ is both } \frac{-a}{+b} \text{ and } \frac{+a}{-b}$$

Hence, the value of a fraction is not altered by changing the signs of its numerator and denominator. The following are instances which should be verified:

$$\frac{p-q}{m-n}=\frac{-(p-q)}{-(m-n)}=\frac{p-q}{n-m}; \quad \frac{p-q}{m-n}=\frac{-(q-p)}{m-n}=-\frac{p-q}{m-n}$$

$$\frac{p-q}{m-n}=\frac{p-q}{-(n-m)}=-\frac{p-q}{n-m}$$

The second expression in each of the following sets arises from changing the sign of one of the letters in the first: the student is required to find out which letter it is, and account for each change.

1. $$a+bx-\frac{1-x}{1+x}-\frac{xx-x}{xx+x}-xx\,(a+xxx)-\frac{1}{x}$$

$$a-bx-\frac{1+x}{1-x}-\frac{xx+x}{xx-x}-xx\,(a-xxx)+\frac{1}{x}$$

* This may be considered as a corollary to the two preceding propositions.

* It may be considered general, since it can be proved true in all cases where actual multiplication is to be performed, and since in mere algebraical calculation it leads to results which we find to be correct.

2. $$ax(x-xx) - bxx(a - xxx) + \frac{x(1-xx)}{ax+ab} - xy$$

$$axx(1+x) - bxx(a + xxx) + \frac{x(1-xx)}{a(x-ab)} + xy$$

3. $$a - bx + cxx - dxxx + \frac{1}{x} - \frac{1}{xx} + \frac{1}{xxx} - \frac{1}{xxxx}$$

$$a + bx + cxx + d\,xxx - \frac{1}{x} - \frac{1}{xx} - \frac{1}{xxx} - \frac{1}{xxxx}$$

HISTORY.

CHAPTER XVII.

THE DAWN OF THE CHRISTIAN ERA.

If we trace back the history of any nation, as far as we can, we find that in its original organization three important functions have been blended into one—the legislator, the priest, and the teacher. The legislator aspires to benefit mankind by introducing precise laws according to which men shall regulate their conduct to each other. A portion of the law is distributive—declaring the rights and duties of each; a part is penal, declaring what penalties shall be awarded to him who transgresses the rules of distributive law; a part is executive, declaring in whom shall be the power of establishing, altering, amending, and executing the law. This is the whole legislative scope of law—the ensuring to each man such a state of security as shall enable him, unmolested and unmolesting, to develope all the peculiarities of his nature. The priest recognises the advantage and necessity of familiarizing the mind with the contemplation of God and eternity,—with man's direct and indirect relations to the infinite and eternal. The object of public, as well as of private, worship is to keep alive by reiterated efforts the impulse of the soul to recognise and bow down before the Divinity, —an impulse more or less inherent in all minds. The object of the teacher's effort is to facilitate the developement of the cognitive, reflective, and combinative faculties in individuals, by communicating the results of the inquiries of others, pointing out the mode in which they set to work, and indicating the means of emulating their efforts. This simple general description will be found applicable to all science and to all instructions in science—the observer of Nature, and he who directs the attention of others to its operations—the moralist and the teacher of morals; all can do no more in the way of science than to accumulate observations, classify, and infer from these other facts beyond their scope of observation, communicate the fruits of their labours, and indicate the means by which the task may be carried on to its completion. Now, the spheres of all the three functionaries mentioned, the objects they have in view, and the means by which they propose to attain them, are quite distinct—the priest seeks to cultivate that in our nature which brings us in relation with God and eternity, to awaken us to a full consciousness of these relations, and, by keeping that consciousness ever vivid and distinct, to preserve and increase the dignity and purity of the individual. The teacher seeks to awaken and strengthen our powers of apprehension, reflection, and invention—to make us acquainted with the stores of nature, and to enable us to turn it to our own uses. The legislator endeavours to provide the means for the due development of men's faculties, in the department of either the priest or the teacher, free from foreign interference—for forcing men to live peaceably side by side, so that each may without hinderance seek by his own efforts, or with the prompting and encouragement of others, the attainment of truth; or, in like safety, aspire to know and control the elements of nature for his own purposes and enjoy the fruits of his own labours. The prosecution of religious investigations presupposes a considerable development of the intellectual powers. Law and religion are branches of knowledge—these three great spheres of man's activity are, like the faculties of his nature, mysteriously intertwined, although distinct—blended and fading into each other at their confines, like the colours of the rainbow, although palpably distinct one from the other. Hence in the infancy of nations, as in the infancy of the individual, the faculties are exerted from the mere conscious pleasure of exertion without any distinct apprehension of their nature, scope, or tendency.

The field of our present inquiry is—1st, The progress of ripening men's minds for the introduction of the Christian Revelation—2d, The Revelation itself—3d, The working of that Revelation—of the third head only a part falls within the limit of the present chapter. It will be resumed from time to time as we advance.

I.—The first head is merely a recapitulation of the events recorded, or alluded to already, concerning the Roman, the Greek, and the Oriental tribes, which passed from the sway of the Persians to that of the Greeks under the subjection of the Romans. In all of these three classes we can trace at least the rudiments of all the three functions of Society: the priestly, the legislative, and the doctrinal—but in each of these, natural character and circumstances combined to promote the development of one in a more rapid and luxuriant form than that of the others. The Legislative predominated. Among the Romans, religion became a mere cold engine of State, and what science the Romans possessed was borrowed from the Greeks. The Greeks did not, like the Romans, wax cold to religion, but their busy and versatile fancies so gained the ascendancy that the character of the worshipper was merged in the artist. They knelt to every impersonation of the beautiful and graceful; they played tricks with their own mind, and lent credence while they knelt even to the fictions of their own inventions. The best recommendation which any Divinity could have to them was their being able to say, it was we who made it so beautiful! This degeneracy of the Greek religion, by which it became little else than a play-thing, was favourable to calling into existence the sages of Greece, and the systematic form given to philosophy and teaching by Plato and Aristotle. The Persian monarchs knew from experience the power of the priests over the multitude, and in every country they conquered they patched up an alliance with them; and by such measures, through by far the greater portion of their dominions, did the priesthood become the natural aristocracy of the country; admission into it was the only means of gratifying ambition, giving development to the national creed, and rendering it more imposing; the national religion thus became the exclusive business of the most aspiring minds. The system of the Persian monarch was adopted by the Greek dynasties, whose founders after the death of Alexander appropriated to themselves Egypt, Syria, and Pergamus, and we have seen what an important part of Roman policy it was to conciliate the various nations incorporated into their states by inscribing the objects of their worship into the catalogue of the national Gods. Thus religion became to be more and more exclusively developed among the nations of Asia Minor, Syria and Egypt, philosophy among the people of Greek extraction, and legislative skill and science among those of Roman progeny.

The Romans, from Cicero to Quintilian, Pliny and Tacitus, studied in the schools of Greece, while in Alexandria the Hellenised Jews busied themselves in endeavouring to reconcile Plato with Moses, or out of the Septuagint and the Platonic dialogues to construct a concrete system of opinions differing from both; and while the glowing Orientals and callous Romans thus sat docile pupils of the Greek sophists, and while Orientals and Greeks drank deep draughts of the legal lore of Rome, such Grecians and Romans as felt the ardour and intensity of their religious yearnings unsatisfied with the shallow superficial creeds of their own races, drank with eager haste and tremulous awe the mystic doctrines of Africa and Southern Asia, glowing like their own scorching climes with burning ardour, yet darkening the soul as the beams of their sun darken the body.

From the foundation of the Empire to the close of the third century of our era, Rome was the capital—the seat to which tribute flowed: the centre to which the busy and ambitious flocked to prosecute their intrigues. It was also the seat of a school of jurisprudence, and frequented by the most eminent teachers of the sciences. Alexandria, the *entrepot* of the commerce of the Mediterranean, the Red Sea, and the upper Nile, was probably the wealthiest city in the empire, and was the seat of one of the chief schools of Greek science and literature, and the only school of the Hellenised Jews. Byzantium was the *entrepot* of the commerce of the Euxine on the one hand, and of the Propontis and the Hellespont on the other. Athens, which formed a central point between Byzantium, Rome, and Alexandria, was of considerable commercial importance, and the principal seat of Greek science. Rhodes, intermediate between Attica and Alexandria; Antioch, between the Mediterranean and Mesopotamia, were seats of commerce and literature. Sicily, Carthage, and the Southern extremity of Italy, might be on an equality with the two last mentioned empires. The flourishing schools of Hebrew literature in Jerusalem and Babylon were formerly adverted to. Massilia, at the bottom of the Gulf of Genoa, was the *entrepot* of the commerce of Great Britain and the Transrhenane world with Rome. Along all the routes connecting these emporia, and in circles extending around each, commerce and intellectual activity flourished: and in

proportion as they flourished were the inhabitants elevated in civilization and refinement.

II.—This hasty retrospect when taken in connection with what has been formerly advanced, will perhaps suffice to shadow out the state of civilization and public opinion throughout the Roman empire at the commencement of the Christian era.

From the rebuilding of Jerusalem down to the time of Antiochus Epiphanes, Jerusalem was a province with a governor of the Persian monarchy in the Greek kingdom of Syria. Under Antiochus the Maccabean family successfully asserted its independence. This family was of priestly rank, and combined, till the extension of the dynasty, the priestly with the regal character; the temporal sovereignty of the Maccabees, however, extended only to the city of Jerusalem and its immediate dependencies. Towards the close of the career of Julius Cæsar, the Herodian family wrested the temporal sceptre from the feeble hands of the last Prince of the Maccabees, and the authority of the magnates of Jerusalem and the rest of the Jews was from that time purely spiritual.

From the time of Ezra to that of Christ, the Jews were a broken and a scattered people, looking to Jerusalem as the centre of their worship, a place where each of them might have a home; elsewhere they had only abiding places. But wherever they sojourned a certain uniformity of character and worship was kept up, and they continued faithful in their obedience to the injunctions of the Pentateuch; though amidst the gradual tendency to decay, and the increasing disasters of the Jewish state, the colleges of the prophets as formerly pointed out, had begun to spiritualize the promises and doctrines of their faith, and this propensity to allegorizo continued till the time of the Christian dispensation. The Pharisees seem to have affected a rigid observance of the law according to the letter; yet even among them the tendency to spiritualize must have crept in from the appeal made to Nicodemus by our Saviour when expounding to him the doctrine of regeneration, "Art thou a teacher in Israel, and knowest not these things?" The Sadducees were a more exclusive and philosophic class, but it is among the sect of the Essenes that we must look for that entire spiritualizing of the ritual law which rendered them "the Society of Friends" among the Jews, and the fitting precursors of the teaching of Christ and his apostles. Thus far the studious classes among the Jews had been advanced, and even the uneducated had been accustomed to popular teachers belonging to the Essenes, who harangued in the synagogues, and allegorized the types and prophecies into moral lessons.

While matters stood in this position, public attention was arrested by the appearance of a Galilean teacher, of whose earliest discourses it stands on record that "the people were astonished at his doctrines, for he taught them as one having authority, and not as the scribes." The doctrines of Jesus Christ are separated by a wide gulf from all which were ever promulgated before him—they do not, with the stoic, substitute the gratifications of pride for those of sense. The spirit of Christianity does not rest satisfied with the negative merit of obeying formal prescripts; it regards man as a denizen of eternity—it teaches him, by raising his thoughts to the perfection of God, by rendering His excellencies the constant theme of his meditation and sympathy, and by constant struggles, to check the untimely motions, and evolve the holy, pure, and benevolent—by persevering in these in confident assurance that renewed efforts, after every lapse of human frailty, will re-purify and at last confirm the graces of virtue and the aspirations of hope and celestial consolation.

After being crucified by those whom his virtues and his doctrines exposed and offended, Christ re-appeared to his disciples, and renewed his injunction that they should promulgate to all nations what he was—the Son of God—and those lessons of brotherly love he had taught them while on earth.

III.—The time of the Saviour's death was amid those high festivals which brought men of the Hebrew faith from every land to Jerusalem, and before the termination of these feasts many converts were added to the church, who carried the seeds of it in their hearts in every direction. Already, before the conversion of St. Paul, there were small societies of Christians to be found in most of the towns of Syria, (taking the word in its widest acceptance), from Mount Taurus to the borders of Egypt, and from the Mediterranean to the Euphrates. The fervid spirit of Paul was the first to burst these boundaries. In repeated excursions he traversed the whole of Asia Minor, Grecia proper, from Athens to Corinth, Attica and Crete, and finally reached Italy and Rome; in all of which places he was instrumental in making converts to the new faith, and in planting churches. The other apostles and evangelists were also similarly engaged in various parts of the East.

It does not appear from any one passage in the New Testament that the apostles, thus employed, contemplated any immediate and direct change upon the structure of civil society by their doctrine. Their object seems simply to have been to rescue men from the penalties of disobedience to the laws of God, through the merits of their crucified master. Nor does there appear to be any especial rules laid down for the government of the churches they established, beyond those of good order and brotherly love. Deacons were appointed to attend to the wants of the poorer brethren and presbyters or pastors for the instruction of the flock, the funds being supplied by voluntary contribution. The members were also in the habit of exhorting one another. Over several such churches we find at an early period an episcope, bishop, or overseer, appointed, and in later times these again became subordinate to an archbishop or patriarch.

The Roman law had always looked with suspicion upon corporations, and thrown impediments in the way of their erection, and their acquisition of property. The disrespect evinced by these new corporations to the popular worship, rendered them still more odious, and considering that men in active political life habitually, like Gallio, "care for none of these things," and that watchful enemies are ever on the alert to whisper calumnies, it is not surprising that repeated persecutions of the early Christians should have taken place. Under these obstacles it was not till the year of the church, 211, that Christian societies obtained the privilege of erecting and consecrating edifices for religious worship, to purchase and hold lands, even in Rome itself, for the benefit of the Christian community, and to conduct the election of their ministers in a public manner. The Christians were now a numerous body; the property of the individual churches was rendered more permanent and stable, and thus increased importance was given to the dignitaries of the church. Their importance was augmented by the brethren avoiding litigation, and submitting all questions of dispute to the decision of their spiritual superiors. When the bishop became the permanent referee of all Christians, he became a judge. By this means, and the fixing of the church property in land and buildings, a similar character was added to the spirituality of the clergy, who even at this early age began to be distinguished from the laity by this appellation. The result of these arrangements was in many instances to degrade the character of the clergy, but it tended likewise to increase the importance, power, and numbers of the visible church.

Thus the church continued growing in worldly power and estimation till the accession of Constantine at the termination of the terrible persecution of Dioclesian. The first Christian Emperor, as Constantine has been called, continued to pay a most suspicious veneration to other Deities than the Christian till the close of his reign. Nor does he seem to have done more than to restore to the Christians the power they formerly possessed of holding lands, and to contribute liberally to many of the churches. He had obtained the empire by standing forward as the patron of Christians, and in return for the assistance they gave him, he advanced them in all civil privileges to an equality with the pagans. Thus far advanced, the scale turned, and Christians, checked only by the brief opposition of Julian, soon gained the ascendancy. But it was chiefly in the Western Church that the policy of Constantine was felt, by the transposition of the seat of Empire to Byzantium. The church of Rome throughout all this period was the most accomplished and worldly wise, and gained a considerable accession to its power. It had kept its place in opposition to the court, and now that the court was removed, there was nothing to mate or match it. Under the few imbecile western emperors, and still more, under the illiterate Teutonic dynasties which erected thrones upon the ruins of their power, it continued to gain in strength. The church was a wealthy body—it was a skilfully organised body—it was an all-pervading body—it could awe the rude superstition even of those who could not be properly called converts. Beneath the protection of the general tolerance of Roman society (the persecutions are the exceptions to the rule) it had grown up into power; it could stand alone—it was vigorous enough to play a more important game among a people who had not witnessed its beginning, who became acquainted with it only in the maturity of its power.

Amid the thousand vague and mystic notions which at that time possessed men's minds, a thousand divarications were prepared of the true gospel. Some would not shake themselves loose from old customs, while others were prompted by vanity to be wise above what was written: not contented with the deep glimpses afforded into that wildest of mysteries, the human heart, by the instructions of Christ; submissive trust, not vain scrutiny, was the proper deportment of a finite being towards the infinite Creator. The empty allegories sprung from the hieroglyphic school—the presump-

tuous sciolism of the Chaldean astrologer—the gloomy reveries of the magi, were drawn upon to eke out the partial glimpses of eternity and infinity allowed to man. A spirit of system and definition crept in among them, formalizing and cramping the gospel, speaking with certainty where humble hope alone was justifiable: an evil which more or less has tarnished every sect till the present day.

The history of the Church even in these early times is often depressing. It seems an incessant monody to the last orally delivered injunction to the curious inquirer after the futurity of another, "What is that to thee? follow thou me." It is melancholy to see the best and greatest so incessantly busied pulling the mote out of their brother's eye without being aware of the beam in their own—and yet, amid all this scandal the gospel is ever vindicating itself. Even amid the darkest aberrations of its professors, there ever and anon plays around some lambent gleam of light from Heaven, teaching us that it is not for us to judge even those who seem most astray. From the time that the leaven may be said to have leavened the whole mass, a higher and purer tone takes possession of society at large, and far inferior though it may be to what the gospel should do, in making men brave, honest, sincere, and humble, that gospel is still there for him who will dare to look at it with his own eyes, and not through the spectacles of the opinions of fallible men. It is in the history of the middle ages, and of modern Europe, that we will be made aware of the essential changes which have been produced in the temper and morals of society by the influences of Revelation.

OBSERVATIONS ON COLOUR BLINDNESS, OR INSENSIBILITY TO THE IMPRESSIONS OF CERTAIN COLOURS.

By Sir David Brewster, K.H., D.C.L., V.P.R.S. Edinburgh.

In a very able and interesting memoir on Colour Blindness, received from my distinguished friend, Prof. Wartmann, of Lausanne, I observe some mistakes respecting my opinions on this subject, which I find it necessary to correct; and I do this with the more satisfaction, as they are not of a controversial character, and as it will give me an opportunity of gratifying the reader with an account of the leading results to which he has been led. The passage in Prof. Wartmann's memoir in which he has mistaken my opinion, is the following:—

"It is well known that the limits of the perception of sound varies in different individuals, as has been demonstrated by Wollaston and Chladni. Sir D. Brewster, reasoning by analogy, supposes that in the case of daltonism, the eye is not affected by the colours of one end of the spectrum. The insensibility of the eyes, in some instances, to make luminous impressions, is explained, he remarks, by assuming that the retina, either from natural examination, or from accidental causes, is less delicate, or less susceptible of the impressions of light in some people than in others."

The opinion contained in the preceeding extract was given in December 1821, and is more an illustration from analogy, than an explanation of the phænomenon. It differs indeed very little from that previously given by Dr. Thomas Young, who attributes colour blindness to the "absence or paralysis of those fibres of the retina which are calculated to perceive red," and it differs nearly as little from the opinion afterwards given by Sir John Herschel, Dr. Elliotson, and Prof. Wartmann himself, that colour blindness arises "*from a defect in the sensorium.*" Now Prof. Wartmann observes, in reference to my explanation as given above, "it appears to me that this theory is not supported by proofs. True,—it not only wants proofs, but it is incapable of being proved, and so is the theory *of a defect in the sensorium*; and so is Dr. Young's theory of a want of proper fibres, or of a paralysis of existing fibres. All these theories, indeed, are mere conjectures, and Dr. Dalton's hypothesis of a blue vitreous humour is the only one capable of being proved or disproved.

As I know nothing about the *sensorium*, or about its connexion with, or mode of operation upon, the nerves of sensation, I shall leave the discussion of the merits of the new theory to those who feel themselves qualified for so arduous a task; I shall content myself with bringing forward some important, and, I believe, new facts, which will at least illustrate, if they do not confirm, the opinion which I have expressed respecting the cause of colour blindness.

In the sentence immediately preceeding the one above quoted by Prof. Wartmann, I state that "I have lately ascertained that some eyes which perform all the functions of visions *in the most perfect manner* are *insensible to certain impressions of highly attenuated light* which are *quite perceptible* to other eyes." Now it was a very natural conclusion that this insensibility might be greater for some colours than for others, and as Dr. Wollaston had just published his discovery of a similar phænomenon in reference to the ears, and had ascribed it to a difference in the state of the tympanum, I conceived that an analogous view might be taken of colour blindness. Perhaps Dr. Wollaston was too bold in ascribing *cricket deafness*, as it may be called, to the state of the tympanum and not to a *defect in the sensorium*, and I also too bold in pursuing the analogy from the *tympanum* to the *retina*. Dr. Wollaston has not mentioned any case, though I have no doubt there are many, in which *cricket deafness* is confined to one *ear*. Although my ordinary hearing is perfect, and each ear equally acute for all ordinary sounds, yet one of them is absolutely deaf to the chirp of the cricket, while the other hears it distinctly. Now it will not, I presume, be maintained that there is a sensorium for each ear. In like manner, and I have no hesitation in predicting it, there may be found persons whose colour blindness is confined to one eye, or at least is greater in the one eye than in the other. Nor is this wholly a conjecture from analogy, for my own right eye, though not a better one than the left, which has no defect whatever, is more sensible to red light than the left eye.

But there are still stronger points to be adduced in favour of these views. I have proved from numerous experiments, that when the retina is rendered partially insensible by the action of light upon any one part of it, *it first becomes insensible to red light*; and hence we have a distinct reason why *red colour blindness* is the general character of the defect under consideration; and I am persuaded, that any defect of sensibility produced by the action of light, or by any other cause, will, if carefully examined, be found to be a maximum with *red* light.

In experiments of this kind, in which what we may call *artificial colour blindness* is produced, the intensity of the light is always diminished; but it remains to be determined, by accurate observation, whether the *red* end of the spectrum (for example) when seen *yellow* by an eye defective in its judgment of colours, is *brighter* or more *obscure* than it would have been had no such defect existed. I am persuaded, from many observations I have made, though I do not consider them as decisive of the question, that the object is seen more obscure, and that certain of the rays emanating from it are not appreciated by the nervous membrane. If, on the other hand, every ray from the red object is efficacious, and the only effect is the substitution of a sensation of *yellow* or *green* in place of *red*, then we might expect that the object would appear brighter, in so far as a *yellow* sensation produced by a given number of red rays should be brighter than a *red* sensation produced by the same number.

After some observations on the foregoing quotation, Prof. Wartmann proceeds thus: "More lately Sir D. Brewster appears to have changed his opinions. On the *supposition* that the choroid coat is essential to vision, he *conjectures* that the red-colour blindness of the daltonians is due to a blue tint residing in the retina, such that the light being deprived of its red rays, by the absorbent power of that membrane, the coloured impression upon the choroid will be deprived of red."

Prof. Wartmann is quite mistaken in thinking that I have changed my opinion; the passage which he quotes as mine is from an *anonymous* notice on the subject, and he was not, therefore, entitled to attach my name to an opinion which I did not avow. It is quite true that I wrote the anonymous notice, but the notice itself, had it been *fully quoted*, would have shown what was my *real opinion*, as distinguished from a *conjecture* founded upon a possible and expressed supposition. The passage, in the anonymous notice quoted by Prof. Wartmann, is as follows:—"Dr. Brewster conceives that the eye is in those cases (of colour blindness) insensible to the colour at one end of the spectrum, just as the ear of certain persons has been proved by Dr. Wollaston to be insensible to sounds at one extremity of the scale of musical notes, while it is perfectly sensible to all other sounds." Now this is my opinion to which, though writing anonymously, I attach my name; and in the very next sentence, I throw out the conjecture, quoted by Prof. Wartmann, from which I withheld my name; and yet he supposes that the conjecture is mine, and attaches my name to it, while he overlooks my real opinion, bearing my name, in the very sentence which precedes the conjecture.

But, after all, the conjecture was not an idle one. During the dissection of many hundred eyes, I observed in several cases that the *vitreous humour* was of a decided *greenish-blue* colour, and in other cases that the *retina* had a marked *French gray* or *pale blue* tint, which decidedly absorbed red light. I knew that in cases of colour blindness, the vitreous humour was not *blue*, or even

greenish-blue, as Dr. Dalton conjectured; but I could not assert that in the same cases the retina might not be blue, and hence I was led to hazard the idea of a blue retina as one which might be admissible as a cause of colour blindness; *but only on the supposition* that the choroid coat should prove to be the seat of vision.

In treating of the various forms of colour blindness, Prof. Wartmann considers the *greatness of their number* as not giving support to the constitution of the solar spectrum of *equal and coincident spectra* of the three primitive colours. "The great number of the varieties of daltonism, appears to me to militate against the proof adduced by Sir D. Brewster, from that analogy, in support of his theory of three elementary colours. It cannot be affirmed that the physiological fact, and the optical principle upon which he bases his analysis of the spectrum, harmonize with, and confirm each other." What Prof. Wartmann calls my *theory of three elementary colours*, is a *fact* as rigorously demonstrated as any physical truth can be; but if he does not admit it as *true* over the whole length of the spectrum, he cannot avoid, if he makes the experiments, admitting it as true over the greater part of it; and this is all that is necessary for my present argument.

I first established the fact, that in part of the spectrum different colours were superposed. In 1827, Sir John Herschel, whose experiments had previously led him to an analogous result, remarks, in his Essay on Light, "that this doctrine is not without its objections; one of the most formidable of which may he drawn from the various affections of vision," namely colour blindness, which he goes on to describe. My principal memoir on the triple spectrum, founded on an immense number of physical experiments, did not appear till 1831; and though I should never have dreamt of bringing to my aid, in such an inquiry, a *physiological fact*, such as that of colour blindness, I found it necessary to remove, if possible, the objection drawn from it by so distinguished a philosopher as Sir John Herschel. My views needed no other support than what they derived from direct experiments with absorbing media applied to spectra, either entire or cut up into bands by the interference of polarized and of common light; but when I believed that I had removed the force of the objection, I was entitled to say that the views in question derived that kind of support which must always be gained by the removal of an objection.

As I do not understand how this negative support can be affected by the great number of varieties of colour blindness, I cannot reply to Prof. Wartmann's statement, but I shall endeavour to explain my own view of the matter. According to the doctrine of the triple spectrum, the red space consists of *red, yellow,* and *blue* light, the *red* predominating and the *blue* being extremely feeble. Now the late Mr. Troughton, whose colour blindness was examined by Sir John Herschel and myself on separate occasions saw this *red space yellow*. Hence, according to my views, he saw a space containing much *yellow* and little *blue*, the *red* light being as it were absorbed, in consequence of the nervous membrane being insensible to its action. If this be the case, there must have been a diminution of light in the red space seen by Mr Troughton, and I am persuaded, from the experiments I have made upon his eyes, that this was the case; but whether it was to the extent of the total defalcation of the red rays, I will not venture to assert. But it is not necessary that it should be so; *the defective perception of red light may be accompanied with a more acute perception of the other colours* in a manner analogous to what takes place in the chemical spectrum, where the removal of the red rays produces an increased action of the rays which are left; the luminous rays may act upon the nervous membrane with negative and positive influences; and this view of the subject is greatly favoured by the results which I published in 1832, relative to the increase in the intensity of light by physiological action. In many cases too of imperfect vision, I have long been of opinion that the retina receives a more powerful luminous impression from yellow light than from the pure white light, of which this yellow forms but a part; and I have therefore recommended the use of yellow glasses as best fitted to excite a torpid retina.

But whether these views be sound or not, I cannot conceive how an *infinite variety*, even in cases of colour blindness, can have any bearing whatever on the doctrine of the triple spectrum. In order to be a case of colour blindness, one or more tints must be wanting or unseen, and there is no tint whatever which cannot be produced by the supposed absorption of individual rays of the compound spectrum.

We regret much that Prof. Wartmann has continued the offensive name of *Daltonism* in his memoir on colour blindness, especially as he agrees with Dr. Whewell in opinion, that no person wishes to be immortalized by bis imperfections. We cannot but regard it as degrading to the venerable name which it misapplies, and as one of the worst examples of vicious nomenclature. The name was first imposed by Prof. Prevost of Geneva, and Prof. Wartmann has continued it on the sole ground that it has for forty years been employed in oral instruction in the academy of that city. Dr. Whewell's name of *Idioptcy* or *Idiopts* is clearly inadmissible, and we cannot speak more favourably of the name *Achromatopsie*, used by Purkinje; *Akyanoblepsie*, used by Goethe; *Chromatopseudopsy*, used by Sommer and Szokalspi; and the last and worst of all, *Chromatometablepsie !* We have used the word *Colour blindness*, because it indicates simply blindness to one or more colours.

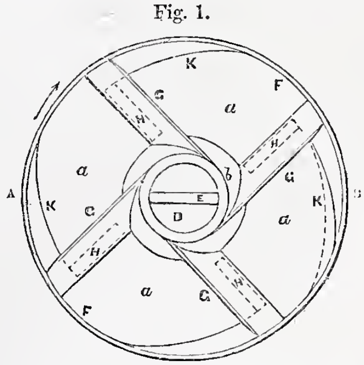
The following is Prof. Wartmann's recapitulation of the principal results of his able and interesting memoir:

1. *Daltonism* has not been studied by the ancients.
2. It has been found only in individuals of the white race.
3. There are very many varieties of the affection, from persons who see only black and white to those who in candlelight confound approximating shades of blue and green.
4. There are more Daltonians than is generally believed.
5. The female sex furnishes a very small proportion.
6. In certain cases they may be recognised by external signs.
7. There are as many Daltonians with *blue* as with *black* eyes.
8. Daltonism is not always hereditary.
9. It does not always affect the males of the same family.
10. It does not always commence at birth.
11. The Daltonians do not judge as we do of complementary colours.
12. Several of them are not sensible to the least refrangible rays.
13. They see, just as we do, the lines in the spectrum discovered by Fraunhofer.
14. They do not judge as we do of the contrast of colours.
15. Daltonism does not arise from a vicious conformation of the eye, or any coloration of the humours or the retina.
16. We may alter the state of Daltonism by very simple means.
17. Daltonism has its origin in a defect of the sensorium.

CONCORAN'S PATENT AERIFEROUS MILLSTONES.

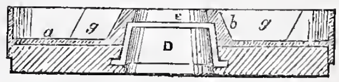
The object of this invention, patented by Mr Bryan Concoran, of London, is to provide means for the circulation of air between the grinding surfaces of the two millstones working together, as usually employed in flour mills, with the view of preventing the material which is ground from heating, which has often a very injurious effect. The annexed figures represent the upper millstone, with the proposed improvement upon it:—Fig. 1, is a plan of the stone,

Fig. 1.



showing the upper side; fig. 2, is a vertical section on the diameter,

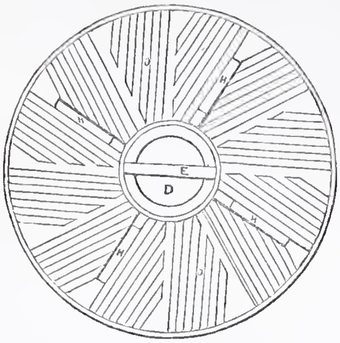
Fig. 2



A B, fig. 1; and fig. 3, is a plan of the under surface of the stone; G is the mill stone; D, the eye-hole, and E, the cross; F is an iron casing, which embraces the periphery of the millstone, and rises above it to some height, as shown in the section; it has a solid bottom at *a*, which rests on the stone, and a boss, *b*, by which it is fixed to the cross E, enabling it to revolve with the boss; G, &c. are four radial vanes, extending between the boss and the circum-

ference of the upper part of the base; they are inclined forwards in the direction in which the stone revolves. At the roots of these vanes there are four passages, H, &c, which go through the metal and stone to the under side. As the stone and case revolve, the air is driven down the passage H, by the action of the inclined vanes, and circulates between the stones by the assistance of the

Fig. 3



channels formed upon the under-surface of the stone; K, &c., are guide plates for the purpose of leading the air to the openings H.

We find also, in the *Civil Engineer's Journal*, an account of Train's Aeriferous millstone, which was one among several that were sent to the French Exposition. In principle, it is identical with the one just described, and varies from it in construction only in having the passages, H, formed in an *inclined* position through the stone, with the view of facilitating the passage of the air. The stones are usually 4 feet 3 inches in diameter—the air passages extend from near the centre to about 5½ inches from the circumference.

DUNN'S PATENT IMPROVEMENTS IN SCREW JACKS.

Mr. Dunn's improvements in the traversing screw jack, of which fig. 1 is a side elevation, consist in mounting a screw jack of the ordinary construction upon four wheels, and by means of a plank raised at one end by a block, forming an inclined plane for the screw jack to work upon. This arrangement is found particularly applicable for replacing a railway carriage upon a line of rails, from which it has been removed some distance, by accident or otherwise. In such a case, the block, *c*, is placed under one end of the carriage; the plank, *b*, bearing on the block, *c*, being inclined towards the line of rails. The screw jack on the wheels, *a*, is then placed on the plank, and the screw turned round until it raises the end of the carriage. As soon as the carriage wheels are lifted off the ground, the carriage, by its own gravity, causes the screw jack to run down the plank, until the wheels of the carriage touch the ground; when this occurs, the screw is again turned, and the operation repeated until the carriage is gradually brought nearer the line of rails, on which the wheels are successively placed.

Removing the screw jack from the wheels, *a*, it may be used for the same purpose as screw jacks in ordinary use.

Fig. 2 represents an elevation of the telescope screw jack, and fig. 3 another view, with the screws turned in. This is well adapted for raising locomotive engines or railway carriages off embankments, or raising any other heavy weights to a greater height than can be done by the ordinary screw jacks.

The conical shaped stand, *d*, is provided with a large circular foot plate, to form a good foundation for the screw jack; the screw, *e*, works in a thread cut in the upper part of the stand, and has a six-sided head, by which it is turned round, the inside of the head forming the nut for the screw, *f*, to work in; the screw, *e*, has a single thread of one-inch pitch, and the screw, *f*, a double thread of one and a half inch pitch. Both screws are shown right handed, but the pitch

Fig. 1.

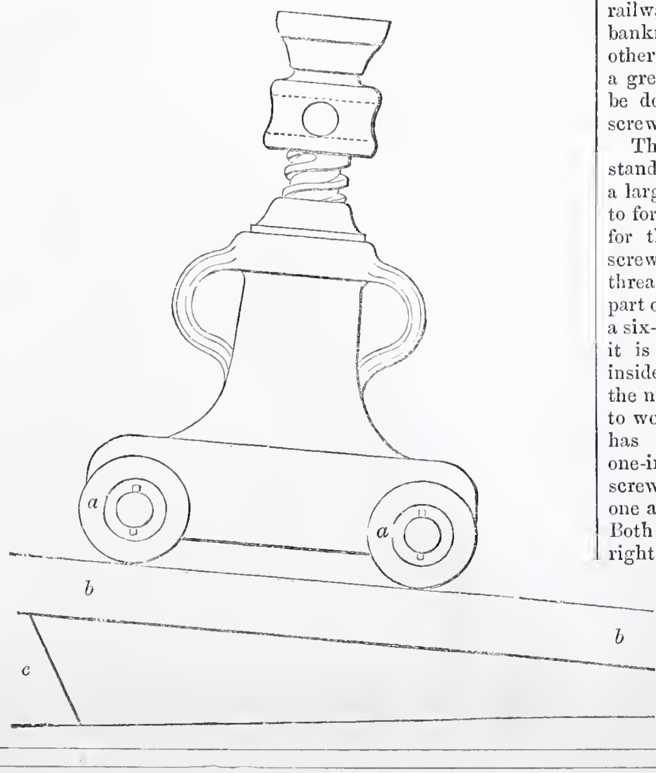
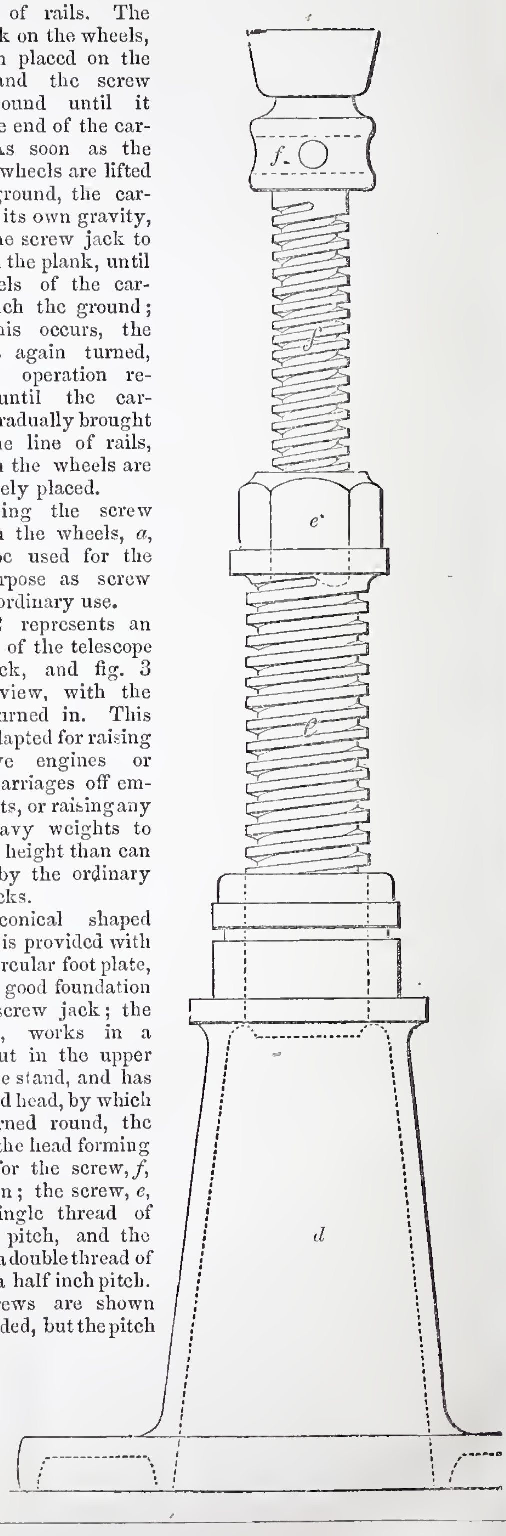
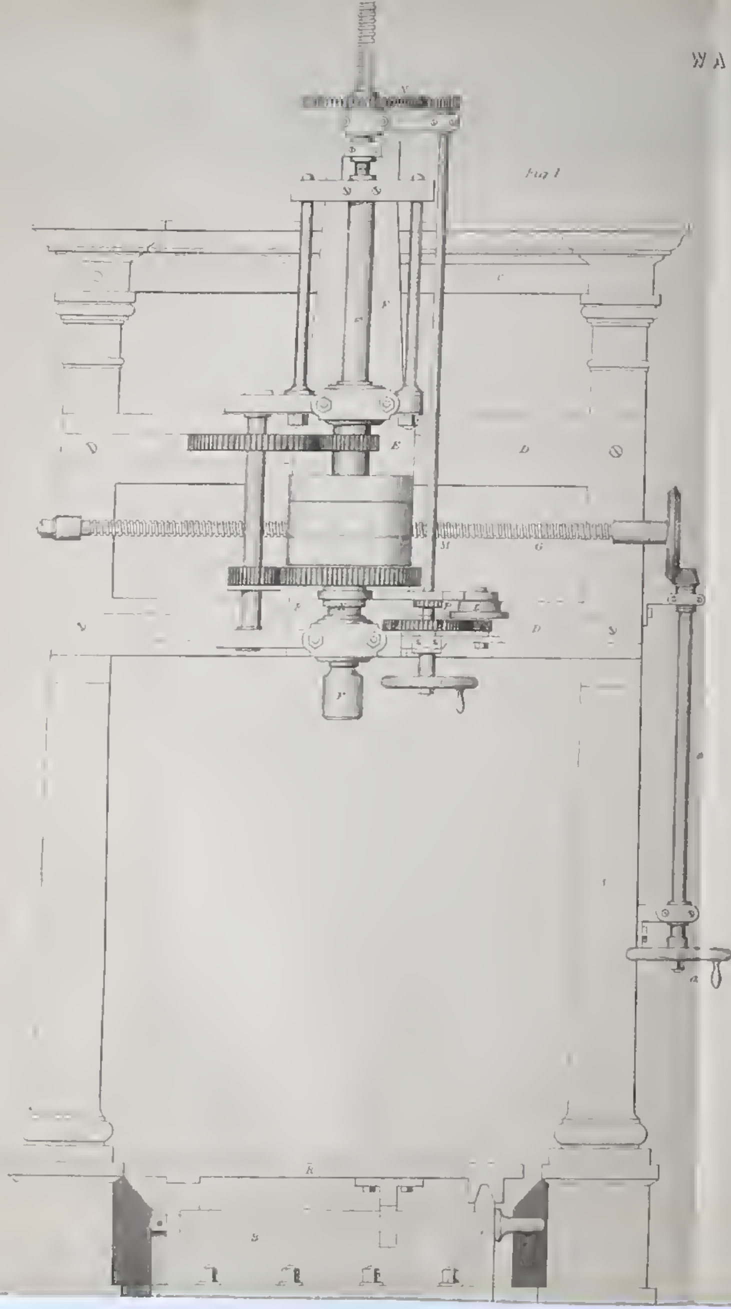
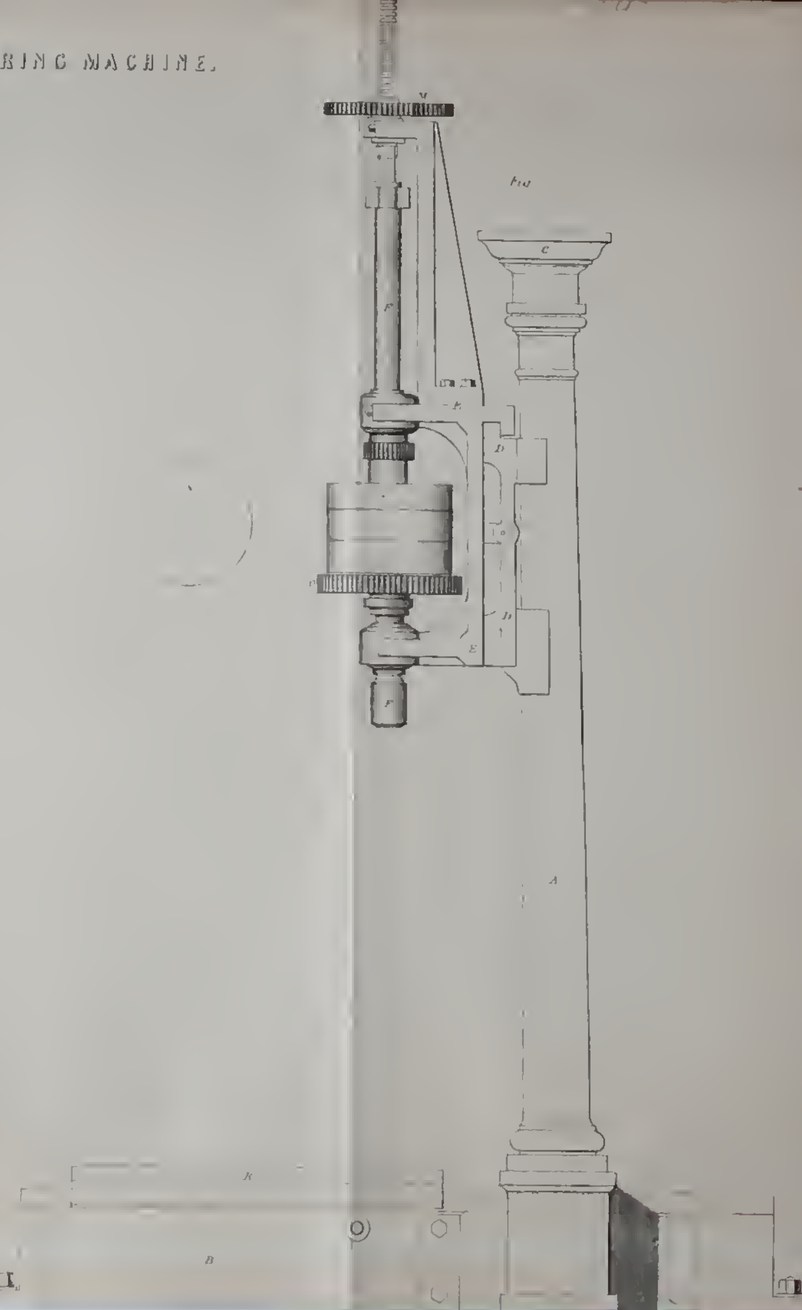


Fig 2.



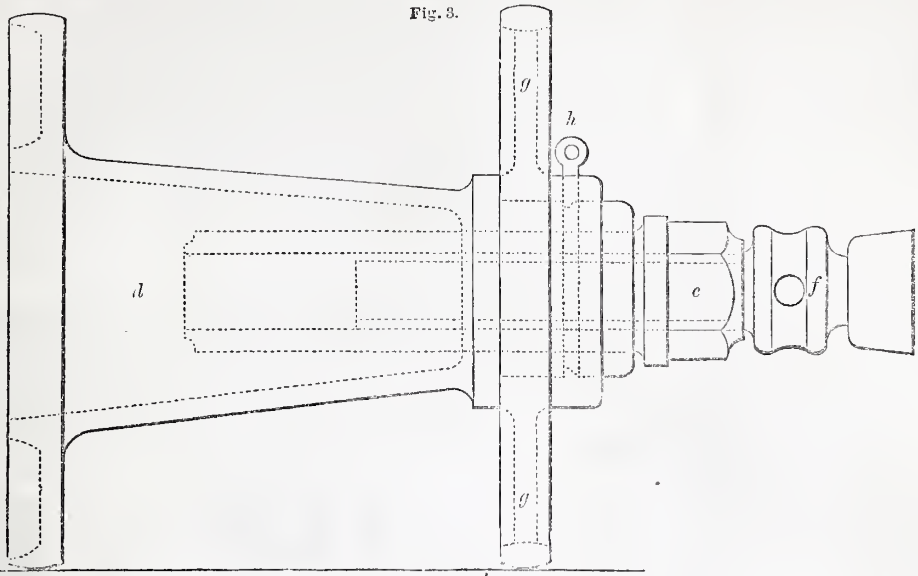
WALTON'S BORING MACHINE.





and the direction of the thread may be varied to suit the particular object for which they are required. If the weight to be raised is comparatively light, by turning both the screws, *e* and *f*, one revolution at the same time, the weight will be raised two and a half inches; if the weight is heavier, the power must be applied to one screw at a time, so as to raise the weight one inch, or one inch and a half, for each revolution; but if the weight to be raised is very heavy, the screws, *e* and *f*, must be

Fig. 3.



turned in contrary directions at the same speed, by which means the weight will only be raised half an inch for one revolution of each of the screws. It will be evident that by varying the speeds of the two screws, the object to be raised may be moved at any velocity, varying from a fraction of an inch to two and a half inches. When the screw jack requires moving, the wheel, *g*, is placed on the stand, *d*, and held in its position by the pin, *h*, working in a groove cut in the stand; the screws, *e* and *f*, are then turned in, as shown in fig. 3, and the screw jack may be rolled where it is required. This arrangement is necessary, as the screw jack, from its weight, would be troublesome to carry. These jacks are made at Windsor Bridge Iron Works, Manchester.

LARGE BORING MACHINE.

BY MR. C. WALTON, LEEDS.

(*Illustrated by Plate IV.*)

This tool was constructed for the purpose of drilling the apertures in the tube plates of locomotive engines for the reception of the tubes. The machine is capable of drilling parallel holes on a surface five feet square, without the necessity of refixing the object on the table, as the head which carries the tool, and the table which carries the object, are moveable in directions at right angles to each other.

Fig. 1, Plate IV., is a front elevation of the machine.

Fig. 2 is a side elevation.

A A are two round cast-iron columns, fastened to the cast-iron bed or gantry, B, by means of bolts and nuts, and connected at the top by a head-piece, C, which is bored out at both ends te receive the tops of the columns, which are secured by a steel pin; D is the horizontal slide, fastened to the columns by means of screws, on which the head, E, slides and receives motion by means of the screw, G, and the bevil-gearing and handle-shaft, *a, a, a*, at the right hand side of the machine, omitted in fig. 2, for the sake of perspicuity. The head-stock, E, contains the spindle, F, for boring, which slides through a long cast-iron socket that revolves in the bearings at each end of the head-stock; the socket receives its motion from the pulleys fixed on it, and the annexed gearing is applied to it for heavy boring, or where slow and powerful motion is required. The socket has also a small cone, K, fixed on it, which by means of a leather belt gives motion to another small cone, L, which has a pinion, *c*, on the end of its socket that drives the wheel, *b b*, on the handle-shaft, M; and on the top of the same shaft is a pinion, *e*, which drives the wheel, N, which is fast on a revolving nut. By these means the self-acting vertical motion is given to the spindle, F. To move the spindle vertically by hand, it is necessary to slide the catch-box pinion, *c c*, out of gear with its clutch, and to use the hand-wheel, O; also, by setting the pinion, *e*, into gear with the wheel, N, it communicates an upward motion to the spindle. The pulleys on the spindle receive their motion from the horizontal drum, S, fig. 2, which is driven at its various speeds by means of a cone pulley fixed on the same shaft, and driven from a reverse cone on the main driving shaft.

By fixing an extra stand on the table, R, of this machine, it is at once adapted for boring small work of different kinds; such as plummer blocks, crank eyes, &c. It may be used with safety for holes as small as half an inch diameter. The table, R, is moved by rack and pinion, and is fastened by bolts and nuts at the corners.

This machine has been frequently adapted to boring locomotive engine cylinders, as the spindle is capable of a vertical travel of 24 inches, which may be increased, if necessary, in the construction of new machines. It will take in a wheel of six feet in diameter, for the purpose of boring out the eye.

IMPROVED LEYDEN JAR.

Subjoined are a drawing and description of an improvement on the construction of the Leyden jar, by Thomas Taylor, of Glasgow, which, from experience, has been found to add very materially to the power of that instrument. The principle upon which the increase of electric power is obtained, depends upon increasing the internal surface, and facilitating the escape of the fluid from the outside. The following description, with the annexed diagram, will make the construction sufficiently apparent.

Fig. 1 is a perspective view of the jar, and fig. 2 its section. A, fig. 1, is a glass jar, twelve inches high, and five wide, coated with tinfoil, inside and outside, in the usual manner, up to E. H is a collar, or hoop, of common tinned iron, two inches broad, half an inch of which is bent over, so as to form a horizontal flange, nicked all round like the teeth of a saw,

forming points for the escape of the electric fluid from the outside surface of the jar. This collar, or hoop, is fitted tightly on the jar at the bottom, as represented at H F. L, fig. 3, is a ground view of this tin hoop, the nicked flange only being visible. C, fig. 1, is a wooden pillar, about an inch thick, and

Fig. 1. Fig. 2.

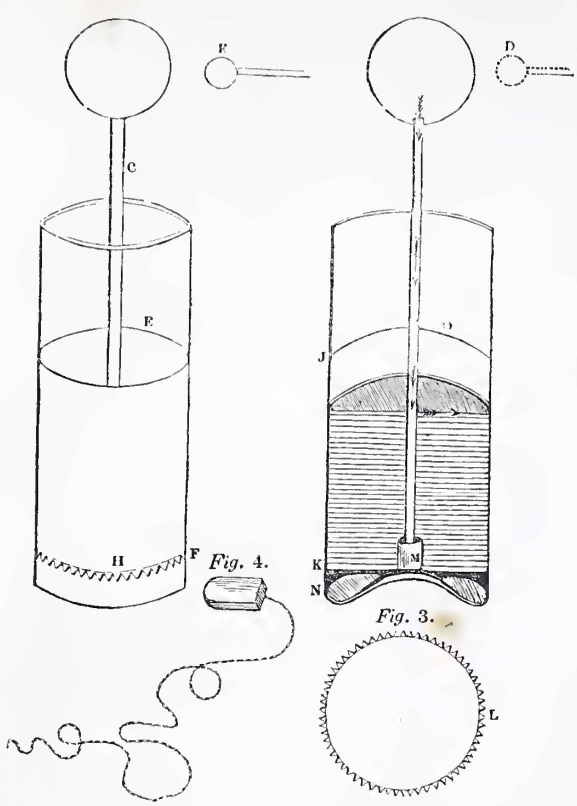


Fig. 4. Fig. 3.

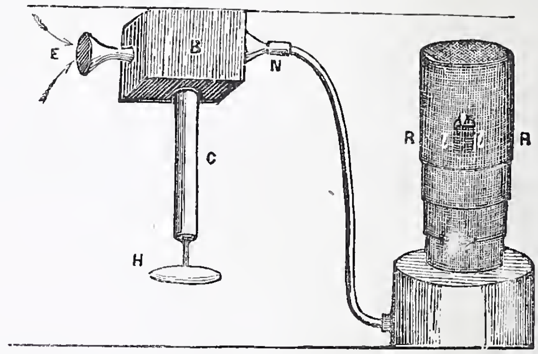
twenty-two inches long, supporting a wooden ball, about $4\frac{1}{2}$ inches diameter, hollow, to render it lighter, and both covered with tinfoil. This ball receives the electricity from the prime conductor of the machine, E, and conducts it to the interior of the jar, which is filled with a series of metallic plates. In the jar constructed by Mr. Taylor, there are 100 of these metallic discs, which may be formed of tinned iron, black sheet-iron, tinfoil, or the thin sheets of lead with which tea-chests are lined, which last is preferable, as being cheap and easily cut. Having cut the discs or plates to the size of the jar, with a hole in the centre sufficiently large to admit the passage of the wooden pillar, they are laid one upon the top of the other, but kept from touching by a disc of cotton net, cut the same size and shape, and placed between them. The 100 plates in the jar, made in this way, and bound together by strong paper pasted round the outside, are about $2\frac{1}{4}$ inches in thickness when in the jar; but it is presumed that, by increasing the number of plates, the capacity of the jar will likewise be increased. To prepare the jar, plaster of Paris must be poured in to make the bottom level, as represented by the light lines at the bottom of fig. 2. A small iron tube, M, to receive the pillar, is soldered upon an iron plate, K, which plate is tacked on to a piece of wood, N, and being imbedded in the plaster of Paris, fits and is fixed in the bottom of the jar. The metallic discs, represented by the lines above K, are then placed in the jar, and the pillar being fitted in the tube, M, the apparatus is complete. The line, J O, fig. 2, is the top of the tinfoil coating. The electric fluid coming from the prime conductor, D, descends the pillar, as shown by the direction of the arrows, and is diffused over the plates. Fig 4 is a small piece of wood covered with tinfoil, to which a chain is attached. This being placed in contact with the hoop, H, when giving any person a shock, all danger of pulling over the jar is avoided.

It will be perceived, that by this arrangement there is a vast increase of surface in the jar; and so great is the increase of power, that the jar constructed by Mr. Taylor, in the manner described, gives a shock equal to a battery formed of nine jars the same size, and coated in the usual manner.

Another experimenter, Mr. A. Thomson, states that, instead of cutting the tinfoil and cloth into circular pieces, he merely cut them into long stripes about four inches broad, and laying the one upon the other, rolled them together upon the pillar, taking care to put the tinfoil next it. He adds that this slight modification of Mr. Taylor's construction, while it does not diminish the power of the apparatus, is a great saving of time, trouble, and material.

PROPOSED APPARATUS FOR BURNING INFLAMMABLE GAS IN MINES.

In the figure, B, is a tight square box, which, when made, is to be attached to the roof of the mine. The box is provided with two valves, one at the bottom of the funnel, E, opening inward, and

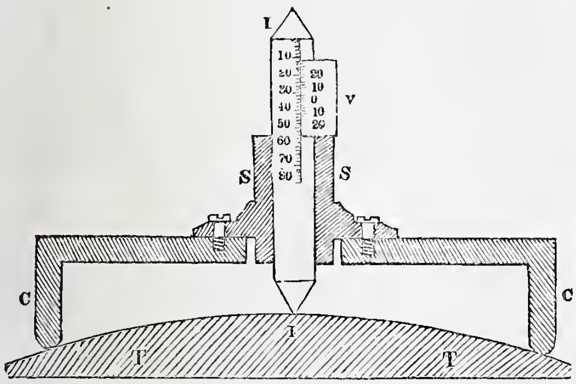


the other in the nozzle N, opening outward. In the bottom of the box is inserted a cylinder, C, into which is fitted a force piston, to be worked by the handle H. On drawing down the piston, the gas will pass into the box through the funnel E; and on returning it up, the funnel valve will shut, and the nozzle valve open for the egress of the gas into the *flexible tube* which connects the collecting box with the combustion apparatus. The receiver, R R, is composed of a series of wire-gauze cylinders, having their upper ends closed with the same material. The second cylinder is made to fit upon the first, the third upon the second, and so on. The ends of the cylinders, below the lamp *l l*, will have the effect of checking any sudden rush of gas into the combustion chamber of the receiver, by the explosion of which the lamp might be extinguished. The ends again of the cylinders, above the lamp, and likewise the overlap of the sides, will have the twofold quality of making the vessel strong, and rendering a communication with the external surrounding gas and the flame of the lamp impossible, otherwise than through its proper channel, the pump. By continuing to work the apparatus, keeping the lamp burning, a mine may be safely divested of any outburst of inflammable gas. If danger, however, be apprehended from this method, the apparatus may be modified thus: provide a number of air-tight bags with nozzles adapted to the nozzle N, and, fitting them to it, fill them in succession with the gas, by working the pump as before; the full bags may be emptied at the bottom of the shaft, and the gas will ascend in consequence of its small specific gravity. This modification would of course cause additional labour, because the bags would always contain more atmospheric air than inflammable gas. This is an inconvenience, however, worth submitting to, should the plan otherwise answer; and in very many cases the labour of emptying the bags might altogether be obviated, by leading the flexible tube itself (making it sufficiently long) to the bottom of the shaft, and allowing the gas to ascend as it escapes through it.

ROSS' SPHEROMETER.*

During a series of experiments, instituted many years since by Professor Barlow, for verifying his method of computing the curvatures of an achromatic object-glass, in which I was practically engaged, it became necessary to ascertain with considerable accuracy the radii of curvature of the tools on which the lenses were ground. The method then adopted was that of grinding in the tool the edge of a plate of glass till the edge accurately fitted the tool, and formed what is called a template. This was laid upon a board in which two pins were inserted, and the template, guided by the pins, was made to describe an arc of great extent. The chord and versed sine of this large arc being carefully drawn and measured afforded data for calculating the radius by the well-known formula, $2\,R = \frac{\left(\frac{c}{2}\right)^2}{v} + v$, where R is the radius, c the chord, and v the versed sine. This, though obviously not a very precise method, was sufficiently correct for verifying the theoretical deductions; and it was as accurate as the processes then employed in working the glasses for telescopes.

With the view of improving these processes, and rendering their results more certain, I have, for more than two years, been carrying on a course of experiments to discover the causes of the discrepancies which were known to exist between theory and practice in this branch of optics. Every improvement in the processes rendered it indispensable to determine more correctly slight variations in the radii of curvature; to accomplish which I was led to invent the instrument of which the description is subjoined.



Its principle and general features are explained in the accompanying sketch, where T T represents a portion of the convex tool to be measured; and as tools are of necessity made in pairs we require to measure only one of each. A short cylinder e e, nearly closed at one end, has its edge very accurately turned and ground to a portion of a circle whose radius is known. In the cylinder is attached a carefully made square socket S S, in which fits and moves the square index bar I I, the extremities of which are furnished with hard steel cones. Upon these conical terminations as centres the circular edge of the cylinder e e is ultimately turned and ground, so that all errors of workmanship in fitting and fixing the socket to the cylinder are completely obviated. The index bar I I is divided on one face to $\frac{1}{50}$th of an inch, and a vernier V is secured to the socket by which it may be read to $\frac{1}{1000}$th of an inch, or, by estimation, to $\frac{1}{2000}$th.

If the edge of the cylinder had been made square instead of circular, then the clear diameter of the cylinder would have been in all cases the value of the chord; but the difficulty of preserving a square angular edge perfectly true, and the different manner in which such a form would lie on spheres of small and large radii, induced me to adopt the circular edge, by which, of course, the value of the measured chord varies with every change of curvature in the tool. To obtain the value of the radius without determining the value of the varying cord I have devised the following formula:—

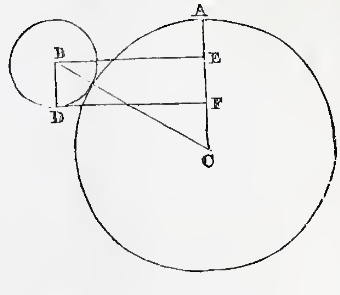
* From the Transactions of the London Society of Arts, Manufactures, and Commerce.

Let B E = F D, the known semi-diameter, or half the distance between the centres of the small circles, which form the edge (which is determined by gently rubbing the cylinder on a perfectly flat surface and measuring the diameter of the ring thus marked on the circle edge) - - - - - - - - - $= a$

A F the apparent versed sine as indicated by the vernier $= v$

E F = B D the known radius of the edge of the spherometer - - - - - - - - - $= r$

A C = the radius of the tool sought - - - - $=$ R



$$\text{Then } AE = v - r$$
$$CE = R - (v - r) = R + r - v$$
$$CB^2 = CE^2 + BE^2$$
$$\text{that is, } (R + r)^2 = (R + r - v)^2 + a^2$$
$$= (R + r)^2 - 2\,v\,(R + r) + v^2 + a^2$$
$$\therefore\; 0 = v^2 + a^2 - 2\,v\,(R + r)$$
$$\text{and } 2\,v\,(R + r) = v^2 + a^2$$
$$\text{or } R = \frac{v^2 + a^2}{2\,v} - r.$$

A SELF-REGISTERING TIDE-GAUGE.

BY MR. JOHN MAXTON, F.R.S.S.A., ENGINEER, LEITH.

The machine represented in the drawings above, was designed by me for registering the amount of tidal rise at any point on the coast, as at a sea-port or navigable river, or in any situation where it is of importance to ascertain the whole rise of the tides for a length of time. Several instruments have been invented for this purpose, and some of these are now in use, it is believed, both in this country and in France; but that which I have invented, and am now to describe, seems more simple in its construction, and promises to be, at least, as well, if not better, calculated to effect the object for which it is intended, than any other construction that has come under my notice.

In figs. 1, and 2, *a* is a plate of $\frac{3}{8}$ths of an inch thick, with dovetailed feathers *b b*, on its surface, between which are grooves represented by the dark spaces, $\frac{1}{2}$ inch in depth; in these grooves are placed moveable *studs, c c*, which are made to slide easily along the whole length of the grooves, and before the machine begins to operate, the whole of them are set near the centre of the plate in two lines, as shown in the upper part of fig. 1. Each groove represents the rise and fall of a tide; and there being two tides in the twenty-four hours, two of these grooves are employed in registering one day's tides. From the mechanism of the machine the studs on the right hand of the centre or zero line are for registering the height; and those on the left, the lowness of the tides as measured from the half-tide level. The figures on the right and left margins correspond to the days of the month; and the drawing represents a register for twenty-eight days' tides, or one lunar month. In figs. 1, and 3, *f* is a pulley with a cord or small chain passing round it; to one end of the cord is attached a float, *g*, (fig. 3.), and to the other end of the cord is a weight *h*, (figs. 1, and 3), which acts as a counter balance to the float. On the axle of the large pulley *f*, is a pinion *x*, and the smaller the diameter of the pinion is, in proportion to that of the pulley, the narrower and more compact the registering plate or table (fig. 1) will be. Letter J represents a rack; the number of teeth and revolutions of pinion *x*, during the whole range of tide, determining the length of the

rack and the proportion of the scales of feet and inches at the top and bottom of the registering plate (fig. 1.) Connected with the horizontal rack, J, is a vertical guide or traversing bar, *l*, which is made to move the whole breadth of the table by its rack and the pinion. At the top and bottom of the vertical bar are pulleys, *m*, for running along the guide-rods, *n*. In the vertical bar there is a groove, in which the sliding bush *z*, is made to move freely up and down ; to this bush is attached a cord, passing over the pulley *p*, at the upper end of the bar, and a constant strain is kept on the cord over the pulley by a weight *q*, to prevent the bush, *z*, from falling downwards. In the bush *z* is a pin which projects into the dovetailed grooves, between the feathers *b*, and slides easily along in them, as the bar *l* traverses either way. This pin moves the studs *c c*, to their proper places for indicating high and low tide. Letter *r*, as will be explained presently, represents moveable tongues or switches, having joints at one end, so loose, that when lifted they will fall down again by their own weight.

Fig. 1.

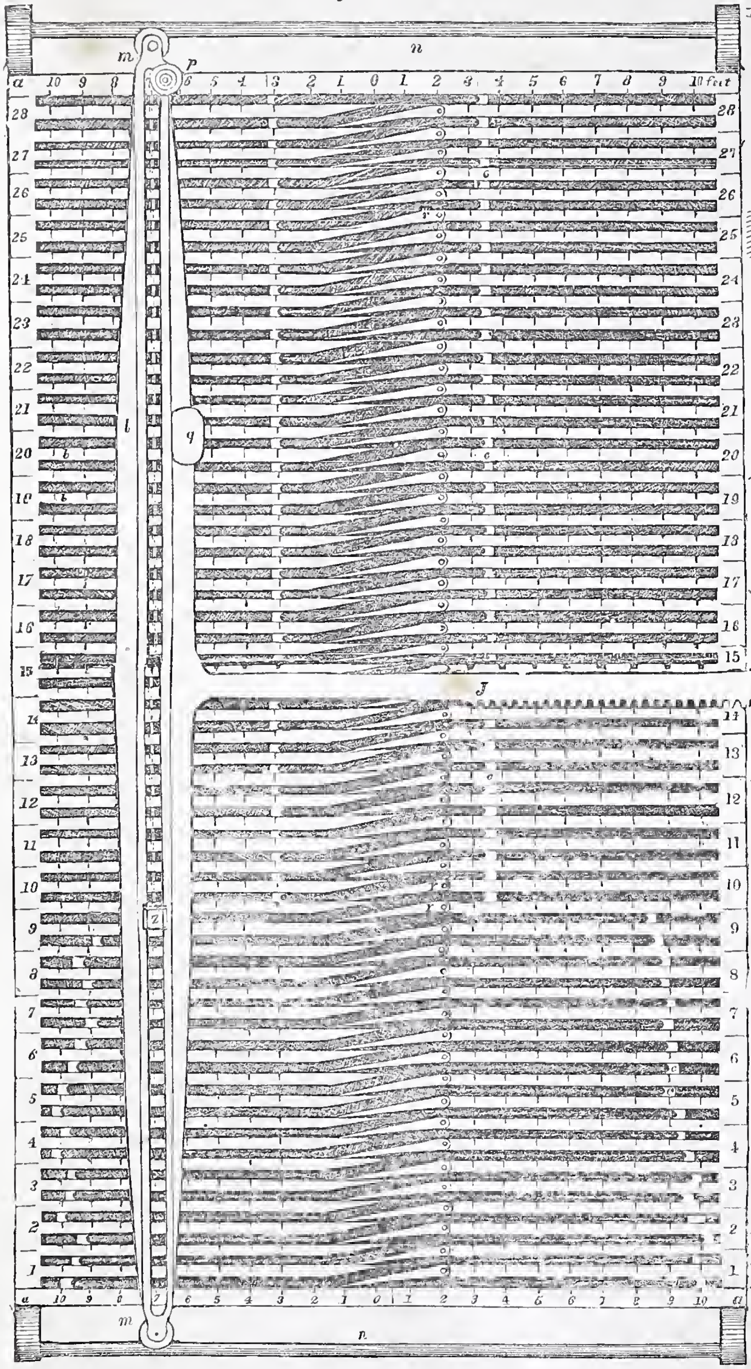


Fig. 3.

Fig. 4.

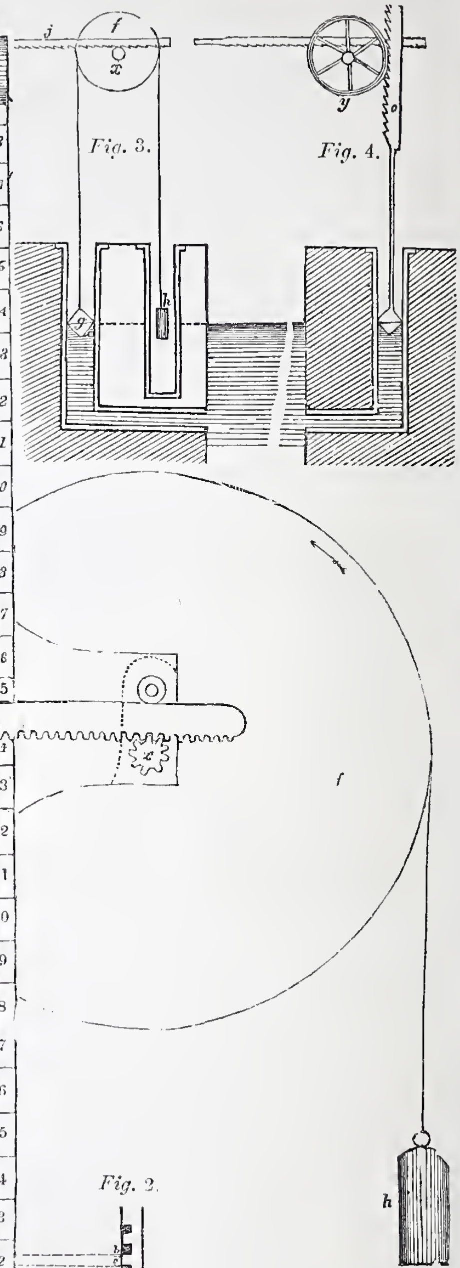
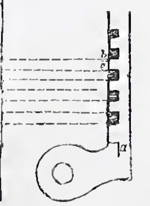


Fig. 2.



We shall suppose that the machine has registered the tides as far as the second tide, on the 9th of the month, as shown in the diagram (the studs below this being all shown as moved to their places, and those in the upper grooves remaining unmoved), and that the tide on the 9th has fallen 7 feet from the datum line (marked 0 on the scale), to this position, therefore, the pin in

the bush z, has moved the sliding stud from the original position in which it was set. Supposing the tide began to flow when the machine was in this last position, by the float g (fig. 3) rising, it would reverse the motion of the pulley and pinion, and bring the rack and traversing bar towards the right, or towards high water, on the table. After having left the sliding piece at its position for denoting low water on the 9th of the month, it is now proceeding towards the sliding piece for denoting high water on the 10th; and when the bush and pin come to the tongue or switch, the pin moves up the inclined plane and on towards the right, moving the sliding piece for denoting high water on the 10th to its right position for that tide. Supposing, now, the tide to ebb, the action of the float reverses the wheel, pinion, rack, and traversing bar, and when the bush and pin come to the under side of the tongue, towards the left, the pin will lift the tongue by the strain produced by the weight q, on the cord which is attached to the bush; and having lifted the tongue, and passed on in a straight line, the tongue falls immediately by its own weight after the pin in the bush z, has passed it; and coming back for the next high water, the pin has to move up the inclined plane as before, and so on with the whole of them.

INORGANIC CHEMISTRY.

CHAPTER IX.

CHEMISTRY OF METALS.

In former times the name *metal* was given to some seven or eight bodies, closely agreeing in external appearance, and as far as their properties were then ascertained, forming a very natural group. To the question, What is a metal? the reply would have been made, a heavy malleable and opaque body of peculiar lustre, solid at ordinary temperatures, but capable of being liquefied by fire, and conducting heat more rapidly than other substances. More recent discoveries have greatly augmented the number of metals, and rendered the above mentioned definition so insecure that, although the power of conducting electricity has been added as a further characteristic, it is frequently no easy matter to decide what is a metal and what is not. The number of metals, as at present recognized, is 50—potassium, sodium, lithium, barium, strontium, calcium, magnesium, lantanum, cerium, yttrium, erbium, terbium, didymium, norium, ilmenium, glucinum, aluminum, thorinum, zirconium, titanium, tantalum, niobium, pelopium, tungsten, molybdenum, vanadium, chromium, uranium, manganese, arsenic, antimony, tellurium, bismuth, zinc, cadmium, tin, lead, iron, cobalt, nickel, copper, mercury, silver, gold, platinum, rhodium, iridium, ruthenium, osmium. The position of some of these is, however, disputed. Arsenic, which volatilizes without fusion on the application of heat, is placed by many among the non-metallic bodies, from its very close analogy to phosphorus. Again, selenium, silicium, and even iodine have been included amongst the metals. There are circumstances which render it at least probable that hydrogen, could it be reduced to solidity, would appear as a metal. It is, in fact, no longer possible to draw any sharp line of demarcation between the metallic and non-metallic elements, and in deciding to which of these two great classes a newly discovered body should be referred, we are guided more by general analogies, than by any specific characteristics. Perhaps, indeed, it would be more advantageous were these classes entirely abandoned, and a new arrangement of the elements introduced, since the one now received scarcely permits us to lay down a single general proposition of any value. What do we learn if told that the substance, x, is a metal? Little more than if simply informed that it is an element. At ordinary temperatures, the metals, with the single exception of mercury, are solid. By an increase of heat they may be liquefied, and even volatilized. The following may be distilled—mercury, cadmium, arsenic, tellurium, zinc, potassium, sodium. The order of fusibility, as far as determined, is the following—mercury, potassium, sodium, tin, cadmium, bismuth, lead, tellurium, zinc, antimony, silver, copper, gold, iron, manganese, cobalt, nickel, palladium, molybdenum, uranium, tungsten, chromium, titanium, cerium, osmium, iridium, rhodium, platinum, and tantalum. Of these, mercury melts at 38° Fah., potassium at blood-heat, whilst platinum only yields to the oxy-hydrogen blowpipe, or the thermic action of a powerful voltaic battery. In specific gravity, they range from 0·8 (potassium, which floats upon water) to 22 (platinum). Some metals are brittle, and may be easily reduced to powder, whilst others yield to blows or pressure. The former are—antimony, arsenic, bismuth, cerium, chromium, cobalt (?), tantalum, manganese, molybdenum, rhodium, tellurium, titanium, tungsten, uranium, yttrium, vanadium; the latter—cadmium, copper, gold, iridium, iron, lead, mercury (frozen), nickel, osmium (?), palladium, platinum, potassium, silver, sodium, tin, zinc, barium, strontium, calcium, magnesium, lantanum, aluminum. Some metals admit of being extended into wire; their order of ductility is—gold, silver, platinum, iron, copper, tin, lead. Their degrees of tenacity, shown by the weight which wires of the same diameter will support—iron, copper, platinum, silver, gold, zinc, tin, lead. Their degrees of malleability, or the extent to which they can be spread out under the hammer, are shown in the following series—gold, silver, copper, tin, platinum, lead, zinc, iron. Their order of hardness is as follows—titanium, manganese, chromium, rhodium, nickel, cobalt, iron, antimony, zinc, palladium, platinum, copper, gold, silver, tellurium, bismuth, cadmium, tin, lead, potassium, sodium, mercury. The first named, titanium, scratches steel and rock crystal. Metals differ little in colour, being for the most part grey; gold alone is yellow, titanium and copper red. They were long supposed to be absolutely opaque, but gold leaf transmits a small amount of light of a greenish hue, and it is probable that a similar phenomenon might be observed in other metals, could they be sufficiently extended. Yet we may say that metals offer a greater resistance to the passage of light than any other body of equal thickness. All possess, when rubbed or burnished, a peculiar appearance called *metallic lustre*. Their order in this respect is platinum, silver, mercury, gold, copper, tin, lead. All the heavy metals, with the exception of iron, are poisonous, yet copper appears, in small proportions, as a normal ingredient of the human blood. They are inodorous at common temperatures, and insoluble *as such*, that is, until they have entered into combination with some other body. Their taste is exceedingly unpleasant. Most of the metals may be obtained in crystals, among which octahedral forms predominate. They not only crystallize during solidification after fusion, but when exposed to continual friction or percussion, as is sometimes exemplified in the axles of railway carriages. The state in which metals occur in the earth, is rather a question of mineralogy than of chemistry; but we may remark that these bodies are found rarely pure, but either combined with oxygen, sulphur, chlorine, and acids, as *ores*, or alloyed with other metals, as gold dust, platinum grains, &c. Concerning the classification of metals, different views have been taken. Berzelius arranges them in a series according to their electric properties; but the growing discredit attached to the electro-chemical theory, renders his system of little value. The most ordinary classifications relate merely to the affinity of the metals for oxygen, and are therefore one-sided in principle. The decomposition of water is no longer of any value as a characteristic, since all metals are able to produce this result at a sufficiently elevated temperature. Gmelin distributes the metals in the following groups:—

A. Light Metals; sp. gr. from 0·860 — 5. Possess a very high affinity for oxygen; many decompose water at ordinary temperatures. Their oxides usually powerful bases.

a. Alkaline Metals, which, by their union with oxygen, form the alkalies, properly so called.

Potassium, sodium, lithium, barium, strontium, calcium.

b. Earth Metals.—Generate *earths* with oxygen. Magnesium, cerium, lantanum, didymium, yttrium, erbium, terbium, glucinum, aluminum, thorinum, zirconium, norium, ilmenium (?).

B. Heavy Metals; sp. gr. from 5·308—22, some brittle, others malleable; melting-point varies. Affinity for oxygen in some instances very feeble. Their oxygen compounds either *heavy basic oxides*, *metallic acids*, *suboxides* or *peroxides*.

a. Base Metals, not reduced by heat alone.

I. Brittle, &c.

1. Difficultly fusible — Titanium, tantalum, niobium,

pelopium, tungsten, molybdenum, vanadium, chromium, uranium, and manganese.

2. Easily fusible, or volatile—Arsenic, antimony, tellurium, bismuth.

II. Malleable—Zinc, cadmium, tin, lead, iron, cobalt, nickel, and copper.

b. Noble metals, reduced by heat alone—Mercury, silver, gold, platinum, palladium, rhodium, iridium, ruthenium, and osmium.

The doctrine of isomorphism (Vol. I. p. 43) has enabled us to recognize several natural groups, which may be here enumerated, as they possess respectively many properties in common, and are often treated of conjointly.

First group—Magnesian Metals—Magnesia, manganese, iron, cobalt, nickel, zinc, copper, cadmium, aluminum, chromium, calcium.

Second group—Silver, sodium, potassium.

Third group—Barium, strontium, lead.

Fourth group—Antimony, arsenic.

A classification of the metals has also been proposed, founded on the colour of their oxides. This idea is not devoid of plausibility, since the coloured and colourless oxide certainly form two moderately well-defined classes. But the colour of a compound is determined, not merely by the chemical nature of its elements, but also by its mechanical structure. Thus, the yellow crystals of iodide of mercury obtained by sublimation, turn bright scarlet if stirred with a pointed instrument, without any change in their chemical constitution. The protosulphide of mercury when amorphous is black, but if violently shaken, it crystallizes and becomes scarlet. Numerous bodies also, such as oxide of mercury, if heated, assume a different colour, and return to their original shade on cooling. Until, therefore, we have ascertained how much of the colour of a body is constitutional, and how much merely structural, we should err in making it a fundamental character in classification.

COMBINATIONS OF METALLIC AND NON-METALLIC ELEMENTS.

The principal of these combinations are those formed by oxygen, chlorine, iodine, and sulphur. The bromides, selenides, phosphides, carbides, and hydrides, are less important and less thoroughly known.

Metallic Oxides.—The affinity of the metals for oxygen varies exceedingly. They are oxidized accordingly by different methods. The alkaline metals are rapidly oxidized on exposure to air or water. The first four earthy metals also decompose water at common temperatures, but the remainder require the addition of an acid, such as sulphuric or hydrochloric. At a low red-heat they ignite and burn with great brilliance, forming their respective oxides. The so-called *base* metals of the next division may generally be oxidized by prolonged ignition; but the most convenient method is in general to treat them with an acid. Nitric acid, at common temperatures, or at the boiling point, oxidizes all metals except titanium, tantalum, platinum, rhodium, iridium, and gold. The latter metal, however, when in a state of minute division, is slowly dissolved by hot fuming nitric acid. Except in the case of tungsten, tellurium, tin, and arsenic, the resulting oxide combines with an undecomposed part of the acid, from which it may be generally separated by the cautious application of heat, or by the addition of potash or soda. The action of nitric acid is very much influenced by its strength, temperature, and freedom from nitrous acid. Of the remarkable phenomena thus presented, we mention here only the *passive state of iron*. Under certain circumstances, namely, this metal may be thrown into a condition in which nitric acid is unable to effect its solution. This state may be produced by heating one end of a wire to redness, or by plunging it for a short time into nitric acid of sp. gr. 1·5. A piece of passive iron communicates the same property to another portion by contact. Friction, the action of chlorine, bromine or hydrochloric acid, likewise contact with zinc, tin, and lead, restore iron to its ordinary condition.

Tantalum and titanium are dissolved in a mixture of nitric and hydrofluoric acids; platinum, rhodium, and gold, in aqua regia. Iridium is oxidized by ignition with a mixture of caustic potassa and saltpetre. The majority of metals may be oxidized, likewise, by means of sulphuric acid. Here, however, we must distinguish two totally different reactions. Certain metals, such as manganese, iron, zinc, nickel, cobalt, dissolve in dilute nitric acid at common temperatures. Hydrogen gas is evolved owing to the decomposition of water, the acid itself remaining undecomposed. Others, again, such as lead, copper, mercury, silver, dissolve only in hot and concentrated acid, which itself undergoes decomposition, sulphurous acid gas being evolved. Hydrochloric acid dissolves such metals only as are acted upon by dilute sulphuric acid. Little can be said in explanation of the fact, that a metal should dissolve in one acid rather than in another. Caustic potash, saltpetre, and bisulphate of potash, at a red-heat, are likewise powerful oxidizing agents. The metallic oxides are either acids, salifiable bases, suboxides, or superoxides. Of these, some metals yield only the first, others only the second, and many furnish, in their different stages of oxidation, instances of both the former classes, along with one or other of the two latter. Thus, mercury forms salifiable bases alone; arsenic only acids; manganese, bases, acids, and a superoxide. The metallic acids have little to distinguish them from those formed by non-metallic elements. Some are very unstable, being decomposed by the action of the atmosphere, or the contact of organic matter, whilst others, such as the chromic, are exceedingly permanent and energetic in their affinities. When existing uncombined they are, for the most part, solid. Their general form is MO^3, MO^5 or $M^2\,O^7$ (M being used in symbolical language to denote any metal not specified); MO^2 and MO^4 are of rare occurrence. Amphoteric compounds, such as can indifferently play the part of an acid or a base, are very frequent amongst metallic oxides. To explain the formation of metallic acids, Persoz lays down the following law:—All bodies which in combination with chlorine form compounds, volatile below the boiling point of mercury, produce acids when combined with oxygen. We may also remark, that all the decided acids are formed from brittle metals.

The salifiable bases are a much more numerous class. Those formed by many of the light metals are soluble in water, and may be recognised by their taste and reaction. The oxides of the heavy metals are nearly insoluble, and their alkaline properties are only manifested by their action upon acids. Their general formula is MO, or $M^2\,O^3$, those of the former type being the stronger; in other circumstances they are equal. The feebler bases are precipitated by the stronger, especially by potash and soda, from their solutions—a reaction employed for obtaining the former in a state of purity. It is observed by Persoz that both acids and bases contain, for the most part, an uneven number of atoms of oxygen.

The suboxides and superoxides, unlike the two former classes, show no disposition to form compounds of higher orders. In contact with acids they are decomposed, a portion either of metal or of oxygen is liberated, and the basic oxide resulting from this process then combines with the acid. The general constitution of suboxides is $M^2\,O$; that of superoxides MO^2. The latter when heated give off oxygen, being reduced to M O (barium, strontium), or $M^2\,O^3$ (manganese), and are hence useful as oxidizing agents.

The separation of a metal from its oxides is termed *reduction*. This is effected by heat alone in the noble metals; in the remainder, by the aid of hydrogen gas at an elevated temperature, or of carbon, iron filings, and potassium at a white heat. Lime has been perfectly reduced only by the galvanic battery.

Chlorides.—The compounds of the metals with chlorine are of considerable importance. Like the oxides they are divided into distinct classes, of acid and basic properties respectively, and capable of entering into mutual combination. The chlorine compounds of a metal generally agree in constitution with its oxides, and form a corresponding series—a remark which applies also to the sulphides. They are however less numerous, no metal having more than four stages of chlorinization, and very few more than one or two. Except chloride of silver, dichloride of copper, dichloride of mercury, protochloride of gold, and protochloride of platinum, all are soluble in water; some to a very great extent. They are frequently soluble in alcohol and ether. Most chlorides are solid at common temperatures, but those of arsenic are liquid, and the terchloride of manganese gaseous.

The affinity of the metals for chlorine is in many cases even greater than for oxygen; zinc, antimony, and arsenic, in fine powder, combine with chlorine gas at common temperatures, with evolution of heat and light. The chlorides are generally formed, either by the direct action of gaseous chlorine upon the metal, by heating the metal or its oxide with hydrochloric acid, or by double decomposition. The chlorides of gold and platinum are reduced by heat alone; those of the remaining metals require to be ignited in a current of hydrogen gas.

The iodides have a very close analogy to the chlorides. They are generally less soluble and exhibit a greater variety of colours. They are formed, either by rubbing iodine along with the metal (mercury), by digesting them together in water (iron, zinc), or by double decomposition (lead, silver). All iodides are decomposed by chlorine, bromine, concentrated sulphuric and nitric acids, and by oxygen gas at a red heat.

Bromine and fluorine have a powerful affinity for many metals, but their compounds are for the most part unimportant and uninteresting. The bromides are principally formed by direct action, the combination being frequently attended with light and heat, or by means of hydrobromic acid, which, mingled with nitric acid, is capable of dissolving gold.

Sulphides.—The compounds of metal with sulphur are frequently more numerous than the corresponding oxides, with which, however, they are closely analogous. Accordingly, as the oxides of a metal are acid or basic, the same will hold good with its sulphides. They are opaque brittle solids; fusible, crystalline; possessing a metallic lustre. All except those of the alkaline metals and earths are insoluble in water. The affinity of many metals for sulphur is considerable; so that if brought in contact at elevated temperatures they combine with incandescence. The sulphides or sulphurets may be formed either by igniting the metal along with sulphur, or by heating a sulphate with charcoal, or by passing hydrosulphuric acid gas through the solution of the metal. Those which contain more than one atom of sulphur, are partially reduced at elevated temperatures. All are decomposed by the joint agency of heat and oxygen, yielding a variety of products. Some of them in contact with water decompose it, and are converted into sulphates.

The *sulphurets* are generally of a dull dark colour; yellow, brown, and black, predominating.

The *selenides* are closely analogous to the sulphides, but from the scarcity of material they have been very insuffiently studied.

Tellurium, although ranking as a metal, forms compounds very similar to the selenides and sulphides, and totally unlike the metallic alloys.

The *carburets* or *carbides* are little known. According to the commonly received doctrine, steel and cast-iron differ from beaten iron merely in containing a larger amount of carbon; but recent researches cast some discredit upon this supposition, and tend to show that the difference between these modifications of iron depends rather upon crystalline texture.

The metallic *phosphides* are little known. A trace of phosphorus exerts a very pernicious influence upon iron, from which, notwithstanding its volatility and high affinity for oxygen, it cannot be entirely expelled, even by protracted fusion. The hydrogen compounds of the metals are few in number. The gaseous hydrites of arsenic, antimony, and tellurium, are the most important. The first mentioned is a fearfully poisonous gas, closely analogous to phosphuretted hydrogen. It is formed by treating an alloy of zinc and arsenic with dilute sulphuric or hydrochloric acid, and is very inflammable.

Concerning the colours of binary compounds, Persoz has endeavoured to establish the following law:—If the higher oxide of a metal is white or slightly coloured, the lower is blue or dark coloured, and when the higher oxide has a dark colour, the lower is white or faintly coloured. The number of exceptions is, however, so great as to render it of little value. The writer proposes the following:—If a body, A, combine with another body, B, in varying proportions, then, if a change takes place at all, with the increase of B, the colour advances from the more refrangible to the less refrangible limit of the solar spectrum, *i. e.*, from violet towards red.

A compound body is generally the less volatile the greater number of atoms it contains, but its solubility appears in many cases to increase.

We next proceed to consider the individual compounds of the more important metals.

1. Platinum forms two oxides, protoxide, Pt O, and binoxide, $Pt\,O^2$. The former is a grey powder, which is reduced at a red heat, and explodes if ignited with charcoal powder. The latter is black, formed by precipitating a solution of platinum with potash, and gently heating the residue. Both form salts with acids; the latter acts also as a feeble acid. Platinum forms two chlorides of analogous constitution; the bichloride is prepared by dissolving the metal in aqua regia, and evaporating to dryness in the water bath. It dissolves in water with a yellow colour; reduced by heat first to protochloride, and afterwards to metal.

2. Gold.—Three oxides, protoxide, Ao O; teroxide, $Ao\,O^3$; perauric acid, $Ao\,O^5$. Unstable compounds; the two former amphoteric. Gold exposed to the action of a powerful electric battery burns, leaving a purple deposit on adjacent objects, the constitution of which is not yet known. The protoxide, a greenish powder, is prepared by boiling the terchloride for a considerable time with caustic soda. The teroxide, which is a brown mass, is obtained on treating the terchloride with magnesia, and removing the latter from the precipitate by means of strong nitric acid. The affinity of gold for sulphur is feeble; it forms two sulphurets of little interest.

With chlorine, gold forms a protochloride, Ao Cl, and a terchloride, $Ao\,Cl^3$. The latter formed by dissolving gold in aqua regia, is a ruby red mass, yielding a yellow solution.

3. Silver.—Suboxide, Ag O; a bright yellow substance deposited from solutions of the oxide in ammonia. Protoxide, Ag O; obtained on precipitating nitrate of silver with caustic potash; a brown powder, reduced at a red heat. Combines with acids. Peroxide, composition doubtful; iron black crystals, deposited on the positive platinum wire, when a solution of nitrate of silver is placed in the electric circuit. Sulphide of silver, Ag S, is formed on passing sulphuretted hydrogen gas through a solution of any salt of silver. Of a blackish grey colour. Forms the yellowish film which gradually covers silver if exposed to fetid exhalations. Protochloride of silver, Ag Cl, is formed by precipitating nitrate of silver with hydrochloric acid or a soluble chloride. A malleable, flexible body; greyish-white, translucent; crystallizes in octohedrons from its solution in ammonia; forms a curdy-white mass when recently precipitated. Insoluble in acids; decomposed by light, forming the blue-black diechloride, $Ag^2\,Cl$. Iodide of silver, Ag I, is a yellow body, formed on adding iodide of potassium to a salt of silver, both in solution.

4. Mercury.—Dinoxide (black oxide), Hg O; formed by rubbing calomel with caustic potassa. A brownish-black powder, without taste and smell, easily decomposed by light or gentle heat. Combines with acids, forming the salts of mercurous oxide.

Protoxide (red precipitate), Hg O; formed by heating the nitrates of mercury until all nitric acid is expelled; or by maintaining mercury for a month at a boiling temperature in a large flask, loosely stoppered with paper. An orange-red, shining, crystalline powder, sparingly soluble in water; of an acid taste; poisonous. Forms a series of salts with the acids.

Subchloride (calomel), $Hg^2\,Cl$; prepared by precipitating a warm dilute solution of mercurous nitrate with excess of common salt; or by subliming four parts of the chloride along with three parts of metallic mercury. A white insoluble powder, tasteless and inodorous, insoluble in water and cold acids; turned black and decomposed by alkalies. Protochloride (corrosive sublimate), Hg Cl; formed by burning mercury in chlorine gas, or by subliming equal parts of sulphate of mercury and common salt. A white, crystalline, translucent body; volatile, soluble in water and alcohol; of acrid taste; very poisonous.

Diniodide, $Hg^2\,I$; formed by rubbing two parts of mercury with one of iodine, adding a little alcohol. A dark green powder. $Hg^4\,I^3$; formed by dissolving in solution of iodide of potassium, half the amount of iodide which it already contains, and precipitating mercurous nitrate therewith. A yellow powder which turns red when heated, and resumes its former

colour on cooling; decomposed by light. Protiodide, Hg I; formed by rubbing equal parts of mercury and iodine together, or by precipitating a salt of the protoxide with iodide of potassium; a brilliant scarlet powder, soluble in iodide of potassium, from which it is redeposited in crystals.

Protosulphide, Hg S. *a*, crystalline form (cinnabar), vermillion; formed by subliming one part of sulphur with four of mercury; a scarlet powder. *b*, black or amorphous variety; formed by passing sulphuretted hydrogen through a solution of the salts of mercury. It is soluble in hot nitric acid with separation of sulphur.

5. Copper.—Dinoxide (red oxide), Co^2 O; obtained by heating the hydrated protoxide in a solution of potash containing sugar. A red powder, which is decomposed by many acids, and combines with some others, forming the subsalts of copper. It gives a red colour to glass.

Protoxide (cupric or black oxide), Co O; formed by exposing its carbonate or nitrate to a moderate red heat. A brown-black powder, easily reduced on ignition with hydrogen or charcoal. Combines with the acids, forming the protosalts of copper. Peroxide, constitution not known; a yellowish-brown powder, decomposed by acids, by a gentle heat, and by exposure to the atmosphere. Cupric acid has not been obtained in a separate state. Some of its salts have been prepared by passing chlorine gas into a solution of potash, in which hydrated oxide of copper is diffused. Their solutions are a beautiful rose colour. Dichloride, Co^2 Cl; prepared by precipitating the sulphate of cupric oxide with aqueous protochloride of tin. A white crystalline powder, which turns a dusky violet in sunlight. Volatile; insoluble in water and dilute sulphuric acid; soluble in hydrochloric acid and ammonia. Protochloride, Co Cl; obtained by dissolving the black oxide in hydrochloric acid, and drying the solution at a temperature of 430°. A brownish-yellow fusible powder, of a caustic metallic taste. Decomposed at a red heat; deliquesces on exposure to the atmosphere, forming a green liquid. Soluble also in alcohol and ether. Copper and sulphur form three compounds, of which the protosulphide, Co S, is a greenish-black mass, formed by passing sulphuretted hydrogen through a solution of the cupric salts. The phosphides of copper are velvet-black; formed by treating salts of copper with phosphuretted hydrogen,

6. Lead.—Suboxide, Pb^2 O; formed by heating oxalate of protoxide of lead in a vessel from which the air is excluded. A dull black powder; decomposed by acids into a mixture of protoxide and metallic lead. Absorbs oxygen if moistened with water. Protoxide, Pb O (massicot, litharge); prepared on the large scale, by heating lead to dull redness on a flat hearth, until it is entirely oxidized; on the small scale by gently heating nitrate of lead in an open vessel. Forms either yellow crystals (cubic and octohedral), or a pale red amorphous powder. It is a powerful base, and combines readily with acids. Insoluble, or very sparingly soluble in pure water. Combines with fats and oils, and promotes their drying. Red oxide, Pb^3 O ; prepared by prolonged ignition of the preceding. On the large scale, this is performed in wide-mouthed horizontal vessels, which are kept for twenty-four hours at dull redness, and frequently stirred. Scarlet, crystalline powder; turns violet when heated. Decomposed by a strong heat and by acids. Sesquioxide, Pb^2 O , a reddish-yellow mass, obtained on adding chloride of soda to salts of lead. Undergoes spontaneous decomposition. Peroxide, Pb O^2; obtained by fusing protoxide with chlorate of potash, and washing the residue, or by treating red lead with nitric acid. A deep brown crystalline powder; decomposed by light, and elevated temperatures. Combines with some bases, whence it is called also plumbic acid.

Chloride, Pb Cl, a white, sparingly soluble body, formed by precipitating salts of lead with soluble chlorides. Iodide, Pb I, yellow, soluble in iodide of potassium. Protosulphide, Pb S, formed by passing sulphuretted hydrogen over salts of lead; black, insoluble. Paint containing any preparation of lead, is blackened if exposed to the exhalations of cesspools, owing to the formation of this compound.

7. Tin.—Protoxide (stannous oxide), Sn O; prepared by heating ninety-four parts protochloride of tin with one hundred and forty-three parts crystallized carbonate of soda, constantly stirring, washing with boiling water, and drying at a very gentle heat. Occurs in three modifications, black, green, and red. Amphoteric, combining both with acids and alkalies. Binoxide (stannic acid), Sn O^2; prepared by oxidizing tin with nitric acid, and igniting the washed residue. A pale-yellow powder; reddens litmus; exists in two isomeric states, which may be traced through all its combinations, both with acids and alkalies.

Protochloride, Sn Cl; formed by distilling tin with calomel; white, translucent, soluble, volatile. Bichloride, Sn Cl^2; obtained by distilling one part of tin with five parts of corrosive sublimate. A thin, colourless, volatile liquid. Bisulphide (Mosaic gold), Sn S^2; prepared by heating together five parts protosulphide, and eight parts corrosive sublimate. Delicate gold-coloured translucent scales.

8. Zinc.—Protoxide, Zn O; formed by heating zinc nearly to combustion in a large crucible, frequently stirring. A white powder; combines with acids. Chloride, Zn Cl; formed by heating one part of zinc filings with two of corrosive sublimate. A grey translucent body; soft like wax, fusible, deliquescent. Iodide, Zn I; formed by heating the two elements together. Colourless, fusible, volatile, deliquescent. Sulphide, Zn S; prepared by heating zinc with cinnibar; a whitish mass, very infusible.

9. Bismuth.—The constitution of the suboxide is doubtful. Teroxide, Bi O^3; formed by gently igniting the nitrate. A pale lemon-yellow powder; combines with acids. Peroxide, Bi O^4; obtained on boiling the hydrated teroxide with chlorite of soda. A brown mass; does not combine with acids. Bismuthic acid, Bi O^5; formed by igniting the teroxide with excess of caustic potassa, the air having free access. Combines with some bases. Choride, Bi Cl^3; formed by heating one part of bismuth with two parts of corrosive sublimate. A brownish-white opaque body; fusible, volatile, decomposed by water. Teriodide, Bi I^3; formed by precipitating salts of bismuth with iodide of potassium. Brown, crystalline.

10. Nickel.—Protoxide, Ni O; prepared by heating the hydrate in a covered vessel. An olive-green powder; forms salts with the acids, and also with some bases. Sesquioxide, Ni^2 O^3; formed by heating the nitrate not quite to redness. A black powder, decomposed at a red heat. Chloride, Ni Cl; formed by dissolving the oxide in hydrochloric acid, and evaporating to dryness. A brownish-yellow mass; may be obtained in the form of golden scaly crystals by sublimation. On exposure to the atmosphere becomes light green, and deliquesces.

11. Cobalt.—Protoxide, Co O; formed by passing hydrogen gas over the hydrated oxide at 600° Fah. An olive-green powder; decomposed by contact with the atmosphere; combines with acids, forming rose-coloured salts, and under certain circumstances with bases. Sesquioxide, Co^2 O^3; obtained on igniting the nitrate of the protoxide. A brownish-black powder; forms unstable compounds with some of the acids. Chloride, Co Cl; formed by dissolving the oxide in hydrochloric acid, and evaporating to dryness. A blue mass of loose texture; turns red and deliquesces on exposure to the air. Iodide, Co I; formed by heating powdered cobalt and iodine in a glass tube; deliquescent; forms a green solution, which turns red on adding a larger quantity of water. Three sulphides are known, Co S, Co^2, S^3,Co S^2, none of which are important.

12. Iron.—Suboxide, Fe^4 O; formed when iron is burnt before the oxyhydrogen blowpipe. Properties little known. Protoxide, Fe O. The base of the protosalts of iron, but not yet known in a separate state. Black oxide, Fe^3 O^4. The black powder formed when iron is heated in contact with the atmosphere. It combines also with acids. Sesquioxide, Fe^2 O^3; formed by strongly igniting green vitriol. A reddish powder. Combines with acids, forming the sesquisalts of iron. All these oxides are reduced to the metallic state by hydrogen and ammoniacal gas at elevated temperatures. Ferric acid, Fe O^2(?), is known only in combination with bases, with which it forms red salts.

Protochloride, Fe Cl; formed by passing dry hydrochloric acid gas over iron turnings at a red heat. White, scaly, deli-

quescent; forms crystalline compounds with various proportions of water. Sesquichloride, $Fe^2 Cl^3$; prepared by dissolving the sesquioxide in hydrochloric acid, evaporating to dryness, and subliming the residue. Iron black, iridescent, crystalline; combines likewise with water in different proportions.

Iodide, Fe I; one part of iron is digested in water with two parts of iodine. The bluish-green solution, boiled down to dryness, yields a steel-grey mass. Iron and sulphur combine in six proportions. Protosulphide, Fe S, is prepared by igniting iron-filings with two-thirds their weight of sulphur in a covered crucible. Treated with dilute sulphuric, or hydrochloric acid, it evolves pure sulphuretted hydrogen gas, for the preparation of which it is generally employed. Bisulphide, $Fe S^2$; formed by exposing the sesquioxide to a current of sulphuretted hydrogen, at the temperature of 212° Fah. Occurs also naturally as iron pyrites; several varieties of which, if exposed to moist air, decompose water, take up the oxygen, and are converted into sulphate of protoxide of iron (green vitriol)—the usual method followed in the manufacture of that salt.

13. Manganese.—Protoxide, Mn O; prepared by igniting the oxalate in a covered vessel. A pale green powder; unites readily with acids, forming the protosalts of manganese. Red oxide, $Mn^3 O^4$; prepared by igniting oxalate of protoxide with access of air. Decomposed by nitric acid; combines with others, forming manganoso-manganic salts. Sesquioxide, $Mn^2 O^3$; prepared by exposing the peroxide for a considerable time to a dull red heat. It combines with some acids, and is decomposed by others. Peroxide (black oxide), $Mn O^2$. Prepared by boiling either of the two preceding in strong nitric acid. Found native in abundance. Used in preparing oxygen, chlorine, &c. Decomposed by heat and acids. Manganic acid, $Mn O^3$; prepared by igniting the peroxide along with chlorate of potash. Known only in combination with bases, as it cannot exist in a separate state. Its salts, manganates, absorb oxygen if exposed to the air, change from green to red, and then contain; permanganic acid, $Mn^2 O^7$. This acid has also not yet been isolated, but has been obtained in combination with water, by treating the permanganate of baryta with an equivalent quantity of sulphuric acid, and decanting the clear solution. A deep carmine red liquid, decomposed by light, by a temperature of 212°, and by contact with a great variety of bodies. Used as a powerful oxidizing agent.

Protochloride, Mn Cl; formed by passing chlorine gas over a strongly ignited mixture of protoxide and charcoal. A rose-coloured crystalline mass; fusible, deliquescent; soluble in alcohol. Forms a crystalline compound with water. Terchloride, $Mn Cl^2$; prepared by adding sulphuric acid to a solution of manganate of potash, until it turns red, evaporating to dryness, dissolving the residue in oil of vitriol, introducing the solution into a tubulated retort, and adding fragments of fused common salt, as long as coloured vapours are evolved. These vapours condense at 5° Fah. to a greenish brown liquid. If the vapour comes in contact with moist air, it forms a dense rose-coloured cloud. Iodide of manganese, Mn I, is a white crystalline deliquescent mass. Bromide, Mn Br, is of a rose colour. The sulphide, Mn S, is unimportant.

14. Chromium.—Protoxide, Cr O; formed on adding caustic potash to a solution of plotochloride. Yellow becomes brown when dry. Forms salts with the acids, mostly of a red or blue colour. Sesquioxide, $Cr^2 O^3$; prepared by passing dry chlorine gas over chromate of potash at a red heat in a porcelain tube; or by igniting bichromate of potash in a covered crucible with its own weight of sal-ammoniac and a little carbonate of soda, and washing the residue with water. The first method produces green crystalline tables, the second, a green amorphous powder. Not decomposed by hydrogen at a red heat. Forms salts with the acids; combines also with water, and with some alkalies. Chromic acid, $Cr O^3$; prepared by mixing ten measures of a cold saturated solution of bichromate of potash with from twelve to fifteen measures of oil of vitriol, and draining the red crystals, which separate as the liquid cools, upon porous stones. Solid, scarlet, crystalline; decomposed by organic matter into green sesquioxide and oxygen. A powerful acid. Perchromic acid, $Cr^2 O^7$; formed by treating chromic acid with peroxide of hydrogen. A deep blue liquid; unstable; forms salts with ammonia and the organic bases.

Protochloride, Cr Cl; formed by passing *pure dry* hydrogen over perfectly anhydrous sesquichloride at a gentle heat. A white velvety substance. Forms a blue solution with water. One of the most powerful deoxidizing agents known. Sesquichloride, $Cr^2 O^3$; sesquioxide is dissolved in hydrochloric acid and evaporated to dryness. Rose-coloured; intensely sweet; deliquescent, forming a green solution.

Chlorochromic acid, $Cr Cl^3$, $2\, Cr O^3$; formed by melting 10 parts of common salt with 16·9 parts of yellow chromate of potash, bruising the resulting mass, and drenching it with 30 parts of fuming sulphuric acid in a large long-necked retort. A splendid blood-red liquid, yielding deep orange fumes; explodes with phosphorus; ignites with alcohol and oil of turpentine, sometimes with great violence.

15. Arsenic.—Arsenious acid, $As O^3$; formed by heating metallic arsenic in the air; prepared on the large scale by roasting arseniferous metals in a furnace, and condensing the fumes in a series of horizontal chambers. It occurs in two crystalline forms, and likewise amorphous. Fusible, volatile, sparingly soluble in water; violently poisonous; of a faintly sweetish taste. It is amphoteric, combining both with bases and acids, though the latter compounds are very unstable. Arsenic acid, $As O^5$; formed by heating arsenious acid in aqua regia, evaporating to dryness, and heating the residue to incipient redness. Solid, colourless, glassy, deliquescent; less poisonous than the preceding; forms salts with bases. The detection of these bodies will be discussed in a subsequent article.

Arseniuretted hydrogen, $As H^3$, has been already described. Terchloride, $As Cl^3$; one part of arsenic is distilled at a gentle heat with six parts of corrosive sublimate. A transparent, colourless, heavy liquid.

Bisulphide, (realgar), $As S^2$; prepared by distilling iron pyrites with arsenical pyrites. Red, translucent, fusible. *Indian white fire* is produced by the combustion of a mixture of twenty-four parts nitre, seven sulphur, and two realgar. Tersulphide (orpiment), $As S^3$; of pearly lustre, orange-yellow, transparent. Pentasulphide, $As S^5$; a lemon-yellow powder. All these sulphides act as sulphur acids, and combine with basic sulphides to form salts.

16. Antimony.—Teroxide, $Sb O^3$. Prepared by digesting the oxychloride with a solution of carbonate of soda, and washing the residue. Solid, colourless, poisonous; combines both with acids and alkalies. Antimonious acid, $Sb O^4$; prepared by roasting the sulphide as completely as possible. A white powder; combines with bases, also with some acids. Antimonic acid, $Sb O^5$; prepared by boiling the powdered metal with nitric acid, and heating the residue nearly to redness. A pale lemon-yellow, solid. Combines with alkalies.

Antimoniuretted hydrogen, $Sb H^3$; prepared by dissolving zinc and antimony in dilute sulphuric acid. Colourless; of disgusting odour.

Terchloride, $Sb Cl^3$ (butter of antimony). The oxide is dissolved in hydrochloric acid, driving off the acid and water, until the residue has acquired the consistence of butter, and the whole then distilled at a higher temperature. A translucent, colourless, solid, crystalline mass; volatile, corrosive.

Pentachloride, $Sb Cl^5$; formed by passing chlorine gas over powdered metallic antimony at a gentle heat. A colourless, heavy, fuming liquid.

Teriodide, $Sb I^3$. The two elements unite with great vehemence; sometimes with explosion. A crystalline brownish-red mass.

Tersulphide, $Sb S^3$, is the usual ore of antimony, and may be artificially formed by fusing its elements together. A blackish grey powder. The amorphous tersulphide, or mineral kermes, may be formed by precipitating antimonic oxide from its salts by means of sulphuretted hydrogen. Pentasulphide, $Sb S^5$; formed by boiling one part sulphide of antimony with one part of sulphur, in a solution of caustic soda or potash; the liquid is then diluted, filtered, and precipitated with dilute sulphuric acid. A yellowish-red powder. Both these compounds are sulphur acids.

The remainder of the heavy metals are too rare and of too little practical importance to render a special enumeration of their compounds desirable in this work. The earths and alkalies have been already reviewed (Vol. I., p. 424), so that we shall merely enumerate a few compounds not there described. Peroxide of barium, $Ba\,O^2$; formed by passing oxygen gas over pure baryta at a low red heat. At a higher temperature it is again decomposed. By thus alternately raising and lowering the temperature, oxygen gas may be prepared to any extent, and at a very cheap rate. The peroxides of lime and strontia are similar in their constitution, preparation, and properties. Chloride of barium, Ba Cl; formed by dissolving carbonate of baryta in hydrochloric acid, and allowing the solution to crystallize. Colourless, soluble, very poisonous; much used in the laboratory as a test for sulphuric acid. Chloride of calcium, Ca Cl; formed by dissolving lime in hydrochloric acid, and evaporating the residue to dryness. Highly deliquescent; hence used in withdrawing moisture from gases. When mixed in a crystalline state with snow, it generates intense cold. Chloride of sodium, Na Cl (common salt); volatile at a white heat, especially along with aqueous vapour. Chloride of potassium, K Cl; very similar to common salt; deliquescent. Iodide of potassium, K I; iodide of iron is precipitated with prussiate of potash; fine Prussian blue is deposited, and the clear liquid is decanted, evaporated, and crystallized. Colourless, slightly deliquescent.

METALLIC PRECIPITATIONS.

If a clean piece of metal is placed in the solution of another metal having a less affinity for oxygen, or, to use the language of the electro-chemical school, more electro-negative than itself, it is partially dissolved, and the other metal is deposited in a free state. Phosphorus and carbon also exert a similar action upon the noble metals. Even copper is extensively reduced by phosphorus. The earthy and alkaline metals, however, are not precipitated. Even dry metallic salts may be reduced by other metals. This principle is practically applied in separating copper from waters impregnated with that metal. Waste iron is laid in the tanks, which is gradually dissolved, and copper deposited in its stead. A good example of metallic precipitation is given by a piece of zinc suspended in a flask filled with a dilute solution of salt of lead. As the zinc dissolves, the lead is deposited in its place in long loose feathery crystals, forming what, from its appearance, is popularly called a "lead tree."

The combinations which the metals form among themselves are called alloys, except mercury is present, when they are termed amalgams. Those which offer any practical importance have been described in a former article.

THE ELECTROTYPE.

CHAPTER IX.

ELECTROTYPE PRINTING AND ENGRAVING—ELECTRO-ETCHING—GLYPHOGRAPHY—APPLICATIONS TO DAGUERREOTYPE—METALLOCHROMES—METALLIC CLOTH—MISCELLANEOUS AND CONCLUDING REMARKS.

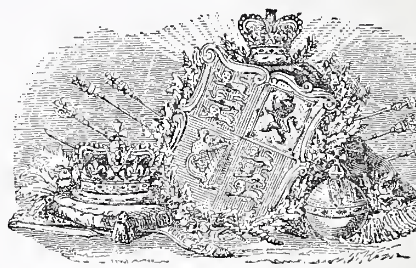
Having now, in the course of the preceding chapters, not only explained the leading principles, a knowledge of which is of the utmost importance to the successful prosecution of electro-metallurgical operations, but likewise given practical instructions for depositing the different metals, it still remains to enumerate some of the principal applications of which the art is susceptible. These applications we shall therefore proceed to describe as briefly as possible; adding, in conclusion, a few of the latest improvements, and some supplementary details, with a view to assist the amateur in conducting the ordinary processes.

ELECTROTYPE PRINTING AND ENGRAVING.

The electro-process, though not hitherto extensively applied to this purpose, may be rendered of considerable advantage to printing in various ways. Mr. Spencer's experiments, on first discovering the process, were chiefly directed to this important object. His success, as may be readily conceived, was only partial; but subsequent improvements have been made, by which the electro-process has been very successfully applied to the copying of copperplate engravings, and even to many operations in ordinary printing. On this subject, Mr. Smee, in a lecture which was recently delivered before the Bank of England Library and Literary Association, has some highly interesting remarks:—

"For the multiplication of type," says Mr. Smee, "the formation of the mould is so difficult that the process is but seldom adopted. Nevertheless, when the electro-stereotype is formed, we obtain a surface for printing of the first excellence, and as very long numbers may be printed therefrom, the process may sometimes be desirable. Copper is found to print far better than the metal of ordinary stereotype. For the multiplication of woodcuts, electro-metallurgy is of higher importance. A mould is taken of the block in gutta percha, which is black-leaded and copied in the usual manner. The gutta percha cut of the coat of arms, which was placed in the solution, (continued the lecturer,) when speaking of the reduction of copper, has already become coated with metal, and after due time will become sufficiently thick for our purposes. This is backed by some alloy of lead, and fixed upon a block of wood, when experience demonstrates

Fig. 1.



that not less than three millions of impressions may be printed therefrom. I have ascertained that the frontispiece of "Punch," the title of "Chambers' Information," and the headings of the "Illustrated London News," publications of enormous circulation, have actually had that number printed from them. By the multiplication of a single block, several impressions may be pulled at once; and here we have a power of production, which enables better works to be introduced into the ordinary operations of life. We are enabled, moreover, from the original design to form two devices, one to print in one colour, one in a second, and I now show you an example of Messrs. De La Rue's operations in this manner. You may think this a trifling matter, but I can assure you that part of the business of their very curious and extensive manufactory is to print labels for certain woven manufactured goods. In foreign countries these are arranged round the stores ornamentally, and, *cæteris paribus*, the sale is secured by the beauty of the ornamental envelope. You thus see that, by printing in two colours, and varying their patterns, our exportations in other directions are favoured, and by that mutual exchange, in which consists the true character of commerce, the whole country is benefited by the modern discoveries of electro-metallurgy. The electro-multiplication of wood-cuts is not so cheap as the ordinary mode of stereotyping; nevertheless, the cast when formed is far more durable and better adapted for the purposes of the printer. I have here an example of a novel mode of the multiplication of blocks by bituminous casts, but nothing can be considered equal to the electrotype for these purposes."

Copperplate engravings may likewise be multiplied to any extent by the electrotype, the process being exactly the same as that of making a copy of a medal or coin. The electrotype mould is first made in copper: on this, of course, the engraving appears in relief; and any number of perfect copies of the copperplate may be deposited successively upon it. "The ordnance maps," says Mr. Smee, "are multiplied in this manner, and by the admirable skill exemplified in this department of

the public service, plates are joined together, or separated, or an original, by a little manual labour, is enabled to become the parent of many offspring, all varying to the extent required." The duplicates thus obtained are accurate copies; but they are unfortunately soon worn away by the friction they undergo in the process of printing; and therefore in ordinary practice, they have not displaced the use of engravings on steel, which prints, without being injured by the process, a large number of impressions. The electro-process, however, is successfully applied to plates for printing music, and for embossing soft materials, such as leather.

ELECTRO-ETCHING.

If the plates of copper in the decomposition cell in connection with the copper of the battery be covered on any part of their surface with a stratum of varnish, that part will be excluded or protected from electrolytic action, while the uncovered part is consumed by gradually combining with the oxygen, relieved at that terminal. Of this circumstance advantage has been taken by coating plates with proper composition, and then tracing through it any design of which an etching is required. It will be observed that, in this case, we are dealing with the positive terminal, whereas the electro-depositions, of which we have hitherto treated, are effected at the negative metal. The process of "electro-etching" is thus described by Mr. Walker:—

"Take a burnished copperplate, and solder to it a stout wire: heat the plate, and rub its surface with etching-ground (which consists of asphalte, wax, black pitch, and Burgundy pitch) wrapped in silk; be careful to obtain an even coating; then smoke the covered surface over the flame of a candle. Varnish the back of the plate, as well as the wire, with shell-lac. Trace the designs through the etching-ground with a fine point. This done, place it in a decomposition-cell, and connect it with the copper of a Daniell's or other battery, placing opposite to it a plate of somewhat similar size; after the lapse of ten minutes remove it, and *stop out* the fine parts with Brunswick black; return it to the decomposition-cell for a second ten minutes; and again stop out the half tints. Again submit it to the action for ten minutes, and the operation is complete. Remove the etching-ground by means of heat, and a perfect engraving will be found on the plate. The exact duration of the several operations, as well as their number, must be regulated according to circumstances. Electro-etching is an interesting experiment for the lecture table. At the commencement of a lecture I have submitted a plate to electric action, and before the hour was expired have distributed proof impressions."

This process possesses some advantages over the ordinary method of etching by the use of nitric acid: the operation can be managed with much regularity, retarded or accelerated at pleasure, and the plate may be taken out and examined from time to time without injury to the process.

ELECTRO-GLYPHOGRAPHY.

In the process of electro-etching no metal is deposited. In this respect it differs from that of glyphography,—a process for which Mr. Palmer, the inventor, has taken a patent. The principle of this invention consists in depositing copper in the etched grooves or engravings, and covering the whole with a sheet of electrotype copper. For this purpose, a smooth copperplate is blackened by sulphuret of potassium, and is then coated with an etching ground, through which a design is traced. It is then brought in contact with a substance having a chemical attraction or affinity for that portion of the composition which remains on the plate, and by this means the high lights of the drawing are raised or thickened all over the plate to any required degree. The whole is then coated with plumbago, and an electro-copperplate is formed from it. Lastly, the metallic plate thus produced is soldered to another piece of metal to strengthen it, and then mounted on a block of wood to bring it to the height of the printer's type, when it is used in the same manner as a woodcut. This is termed an electro-glyphographic cast.

The process has been varied and further improved by the patentee; but we think it would not be consistent with our plan to enter into more extended details. "It confers on the engraver," says Mr. Smee, in the lecture from which we have already quoted, "a new power, as it is the best and cheapest mode now known for the formation of blocks from which maps can be printed. Already the public have the advantage of this addition to our manufacturing operations, as very excellent maps are now being sold at one penny a-piece; and we can hardly estimate the effect of this cheap circulation upon the education of the people. This process also admits of small maps being introduced into the text of books." It must be admitted, however, that up to the present time the process has not come into general use as a substitute for wood engraving, in consequence of the impossibility, hitherto experienced, of finding a suitable varnish for the use of the artist or engraver.

APPLICATIONS TO DAGUERREOTYPE PURPOSES.

The electrotype has been applied, with greater or less success, to the preparation of plates for the daguerreotype, and also to the copying and electro-etching of daguerreotype pictures.

Daguerreotype plates may be prepared, either by plating a burnished and prepared copperplate, or by depositing silver on a burnished plate, and afterwards *backing up* with copper. By those who are not accustomed to the operation of burnishing, the latter will be found the most eligible method; and in this way, as Mr. Walker remarks, "the lovers of this attractive art may now experiment on plates of their own preparation." The process of electro-plating, or coating with silver, was fully detailed in last chapter. The electrotype is not only useful for preparing daguerreotype plates, but has likewise been applied to the copying of daguerreotype pictures. "What may be justly termed the perfection of electrotyping," says Mr. Napier, "is the production of electrotypes from daguerreotypes. The daguerreotype picture being taken, a small portion of the back is cleaned with sand-paper, taking care not to allow anything to touch the face; a little fine solder is placed on this part; a piece of flattened wire, also cleaned, is placed upon the solder, the whole moistened with dilute muriatic acid, or chloride of zinc. The wire is now held over the gas or a lamp about half an inch from the plate; the heat is transmitted through the wire to the solder, which melts, and the wire is soldered to the type; the back is then protected by wax, and the daguerreotype is now put into the copper solution in the same manner as a medal; the deposit proceeds rapidly, and when sufficiently thick the two easily separate, and an impression of the picture is obtained from the daguerreotype, with an expression softer and finer than the original: several electrotypes may, with care, be taken from one picture. The electrotype may now be passed through a weak solution of cyanide of gold and potassium, with the smallest quantity of electricity connected, and thus a beautiful golden tint be given to the picture, which serves to protect it from the action of the atmosphere; but they should also be protected by a glass."

We may add that electro-gilding has been applied with success in protecting and permanently fixing the daguerreotype pictures themselves. The value of this process arises from the well-known fact, that thin films of gold are transparent; and therefore, when a very thin film is deposited, it does not in the least obscure the picture, but even adds to its softness and beauty, while effectually protecting it from injury by atmospheric influence.

Another curious electrotype application is to the purpose of electro-etching daguerreotype plates. In the common process of electro-etching the picture must first be traced by the hand of the artist; but in this it is traced by the mysterious finger of light, and afterwards etched or engraved by the equally mysterious agency of electricity. To render intelligible this process, we may remark that in daguerreotype pictures the dark portions are considered to be silver and the light mercury; and hence to produce an etching on the plates corresponding to the sun-picture impressed upon them, it is necessary only to place them in some solution whose liberated element shall act on one of these metals, and not on the other; or which shall combine with the one more rapidly than it does with the other. For this purpose, muriatic acid has been used, diluted with half its bulk of water; and the negative plate which is found to be

in practice the best for connecting with the positive daguerreotype plate to be etched, is either platinized silver or platinized platinum. The two plates should be parallel, and the distance between them about the fifth of an inch. M. Fizeau, who has been very successful in the practice of daguerreotype etching, inserts the plate in a mixture of nitric, nitrous, and hydrochloric acids, by which means the black or argentine parts of the picture are eroded: he washes out with ammonia the chloride of silver thus formed, and again immerses the plate in the acids, repeating the process several times. He then rubs linseed oil on the plate, and having partially washed it off, he gilds the parts in relief by the electro-process. The oil is then perfectly removed by caustic potash; and he bites in the hollow parts with nitric acid, so as to augment the depth at pleasure. Finally, to adapt the plate for printing—a process by which the silver would soon be worn away—he coats by electro-deposition the entire surface with copper.

It will be observed that, by these processes, a plate is obtained which affords a positive picture, or one which has its lights and shadows as in nature, and not reversed as in the original daguerreotype. It must be admitted, however, that although the etching produced by this process is perfect, the printing from the etched plate is found to be exceedingly difficult, if not a practical impossibility, because of the extreme lightness of the etching; and the very cleaning of the plate by the printer is found to destroy the delicate tracery. The plates may be etched, indeed, to a sufficient depth to produce a satisfactory impression, with ordinary printers' ink, but in that case the finer lines of the original are necessarily run into each other, and the exquisite beauty of the image which was traced by the matchless agency of nature, is thus marred and destroyed.

Still, the engravings that have thus been produced are remarkable; and we may anticipate further improvements, fitted to render practically useful this very beautiful process—yielding engravings, on which it has justly been remarked, that instead of inscribing the words "drawn by Landseer and engraved by Cousins," the artist may write the startling inscription—"*Drawn by Light and engraved by Electricity.*"

METALLO-CHROMES.

Not only may *metals* be deposited on other metals by the electro-process; *metallic oxides* may likewise be deposited in this manner, either for the purpose of protecting the metal to be coated from the action of the air, or for the production of those very beautiful coloured figures known as metallo-chromes.

The metallo-chromes are prepared in the following manner—A saturated solution of acetate of lead is poured into a shallow vessel, in which has been placed a steel plate highly polished. A wire from the positive end of a battery is brought into contact with the plate, and another wire from the negative end is held in the solution immediately over the plate, when a tinted circle will be found to appear on the polished surface of the plate beneath the wire, and rings of colour of very brilliant hues will speedily rise from the centre and expand outward. The colours, as described by Nobili and Mr. Gasscot, commence with silver-blond and advance to fawn-colour, from which they pass through various shades of violet to indigos and blues; then through pale blue to yellow and orange; and thence through greenish violet and green, to reddish yellow and rose lake, which is the highest colour on the chromatic scale. By modifying the shape of the electrode connected with the negative end of the battery, coloured figures varying in character are obtained—by using, for example, instead of a point, a slip of metal—a ring—a cross, or other pattern. "The best metallo-chromes," says Mr. Walker, "are obtained by cutting a star or other pattern in card, and placing the pattern on the plate, beneath a convex or a concave disc." These colours arise from the incalculably thin films of oxide of lead deposited on the steel plates, and are referable therefore to the same cause as those which appear in the soap-bubble, or in the adhering film of air between a lens and a plate of glass, which Sir Isaac Newton explained with so much ingenuity as actually involving the theory of all the colours in nature. The metallo-chromes are very beautiful, but have not hitherto been turned to any account except as illustrations of the colours produced by thin plates.

METALLIC OR COPPERED CLOTH.

Cloth may be coated with copper by brushing it over with a polish of black-lead, and stretching it on a frame of wood encircled with a copper-band, to which the cloth is attached by hooks of the same metal. The whole is inserted in a vat divided by water-tight partitions, and in one of the divisions is placed the dilute acid and zinc, in the other the solution of copper with the cloth stretched upon its frame. By this means pieces of cloth of the dimensions of twelve yards in length by one in width, have been perfectly covered with copper in the space of one hour; and one pound weight of copper was found to give a solid covering to twenty superficial feet of cloth. Considerable quantities of this material were formerly prepared by the Messrs. Elkington, for covering roofs, waggons, &c.; but although exceedingly well adapted for many important purposes, and more especially as fire-proof covers for buildings and waggons, the expense of its preparation was found to be too great to admit of its successful competition with the substances already in general use for similar purposes.

MISCELLANEOUS AND CONCLUDING REMARKS.

Before concluding our remarks on the electro-metallurgical art, which has now been placed before the reader in all its more important relations, both theoretical and practical, we may recur to the process of amalgamating zinc plates, and some other matters of minor detail, which have either been omitted or somewhat cursorily noticed in our former chapters on the subject.

Cast plates of zinc are negative to milled or rolled zinc, and give less electrical power. They are likewise so porous that no amalgamation will protect them from the action of the acid. The latter should therefore be used in electro-metallurgical operations; and amalgamation is performed by placing a little mercury in a saucer or plate, pouring on it some water and sulphuric acid, and brushing the liquid and mercury over the surface of the zinc till the whole is covered with a bright amalgam of mercury.

Another process, submitted by Mr Walenn at the meeting of the British Association in 1849, is as follows:—"After the plates are cleaned with emery, immersion in dilute sulphuric acid, and then in water, they are dipped into a mixture of about equal parts by measure of saturated solutions of chloride of mercury (corrosive sublimate), and acetate of lead; they are then rubbed with a cloth, and are ready for use." It is stated that by this method of preparing the plates, local action is entirely prevented, and they only require one preparation until they are quite dissolved.

When the battery is only to be used for a short period at a time, a very convenient method of amalgamation is to rub over the plate with a solution of nitrate of mercury, after having placed it in sulphuric acid diluted with eight parts of water till the surface is perfectly bright and clean.

Whichever method is adopted, the plate must always be properly cleaned before applying the mercury. The latter may be rubbed upon it with a little tow tied to the end of a piece of wood, and is, of course, to be applied to both sides of the plate. The process of amalgamation should never be omitted by the amateur on the score of economy; for very little mercury suffices, and much trouble is occasioned by the necessarily frequent renewal of plates that have not been amalgamated. A plate of a foot square, amalgamated on both sides, will not retain more than three ounces of mercury. "The most economical way," says Mr. Napier, "of using zincs is this: after being in the battery twenty-four hours, they are to be taken out, brushed, and laid aside; after other twenty-four hours, they are to be again brushed, and *immediately* reamalgamated: if these directions are attended to, half an ounce of mercury will be sufficient for one foot square of zinc, both sides."

When amalgamated zinc and sulphuric acid are used, a highly important consideration is the purity of the sulphuric acid—so far, at least, as that it shall be free from the presence of nitric acid. On this subject, Mr. Walker's remarks are worthy of special attention: "Very commonly," he says, "a small portion of nitric acid is present, and this operates in a

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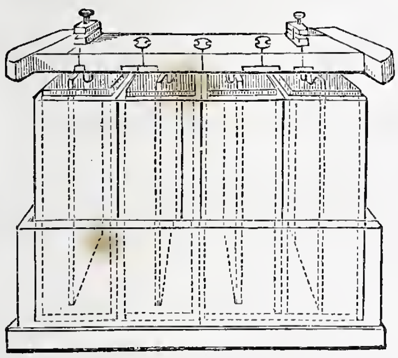
most destructive manner upon the zinc, defying all care and trouble in amalgamation, for it attacks some of the mercury, and leaves portions of the zinc exposed, giving rise to an amount of local action of no trifling extent. This will explain the cause of amalgamation's failing, far more effectually than the assumption of the impurity of the zinc." The presence of nitric in sulphuric acid may be tested in the following manner. Mix with the sulphuric acid, in a Florence flask, some sulphate of indigo; apply heat, and if the blue colour disappear, it may be concluded that nitric acid is present; if the blue colour remain, the acid is sufficiently pure for use. This pure acid should likewise be employed in the process of amalgamation; and "when these preeautions are taken," adds the same writer, "the common rolled or cast zinc may be employed with impunity, and a *perfect* action will be obtained."

Mr. Walker, in the later editions of his work, mentions a a good economieal substitute for Smee's battery. "I have been employing," he says, "with slight modification, an ordinary *acid* battery, namely, a chemico-mechanical battery, in which roughened copper is used instead of platinized silver, and I find it admirably adapted to the purpose of electrotype. Other circumstances being the same, it requires nearly twice the time of a sulphate battery; but this is in a degree compensated by the fineness of the deposit obtained, and the trifling expense attending its use." To make the battery, Mr. Walker coats the interior of a jar with copper by the electro-process, continuing the action until the solution employed for this purpose is nearly exhausted. The surface of the copper obtained by this means presents an infinite number of small points, which very readily part with the hydrogen—the use of the platinized silver in Mr. Smee's battery. "This arrangement," Mr. Walker continues, "may be adopted without the use of diaphragms. Amalgamated zinc is employed. I find that this kind of battery, variously arranged, is greatly used in the arts. Sometimes a single battery is sufficient; at other times, a series of two, three, or four, having the zinc of one connected with the copper of the next, as in this engraving. I have myself been of late operating with the battery on a large scale, using surfaces of from 10 to 14 square feet—if the copper surface has been exposed to the air for any time, while the battery is out of use, it should be well washed with acid water, or the old solution of zinc, before using it again, in order to remove any oxide of copper that may be there. Under these circumstanees, I have every reason to be satisfied with its action, and to prefer it, from its simplieity and steady action, to any other form."

Fig. 3.



An attempt has been made, with partial success, to substitute the magneto-electric current, or the electricity obtained from magnetism, for the voltaic action, in the deposition of metals. This process was patented by Mr. Woolrich, of Birmingham, and Mr. Elkington, of that town, is now the proprietor of the patent. "Within the last few years," says Mr. Smee, in his lecture already quoted, "the electric power has been derived from an entirely different source, [different, namely, from the voltaic battery,] as it has been discovered that a spark could be drawn from a natural or artificial magnet. When I was a student, this phenomenon was a mere philosopher's spark, but now it has been brought to praetical account, and some of these exquisite candelabra have been silvered by Messrs. Elkington, through the agency of this power. Last summer, by the kindness of Mr. Lucy, the Mayor of Birmingham, I was one of an exhibition party who had an opportunity of witnessing the manufacturing triumphs of that great town. At Messrs. Elkington's, we then saw a large magneto-electric machine, worked by a steam-engine, and which was computed to reduce fifty ounces of silver per day. You thus see that no one should ever despise a philosopher's spark, for it is impossible to foretell to what important conclusions it may lead." We may add that the power obtained from the electro-magnet, though ample for the reduction of silver and gold, is not at present sufficient for the economical reduction of copper.

With this ultimate triumph of the art, expressed in the appropriate language of one who has largely contributed, both by his writings and researches, to confer on it its present high position, we shall bring to a close the present series of papers on this very interesting subject. We have touched on all its more important relations, and we trust our remarks have been sufficiently explicit, in point of theoretical exposition as well as practieal detail, to enable the amateur to cultivate the art with success, and with that degree of gratification which arises from a knowledge of principles. Regarded in this light, that which may be practised by some as a mere amusement, becomes a vehicle of highly useful instruction, and turns the attention into channels of inquiry through which it is led, from comparative trifles, to the contemplation of the highest discoveries of science. How wondrous and instructive the fact, that the agent which is called into exercise in gilding a ring, or in etching, with silent and delicate touch, the beautiful daguerreotype-images traced by the magic pencil of Light, is the same which awes us by the terrible displays of its power in the thunderstorm, and which at the same time is girdling the earth with intelligence, and speeding through the slender wire, and even through the depths of the ocean, with tidings of civilization and progress!

GEOGRAPHY.

CHAPTER VI.

SUBDIVISIONS OF EUROPE—COMPREHENDING A BRIEF SKETCH OF ITS DIFFERENT KINGDOMS.

THE BRITISH EMPIRE.

THE British Empire consists not only of the United Kingdom of Great Britain and Ireland, but of numerous and extensive territories and colonies in every quarter of the world; so as to give room for the apparently boastful assertion, that the sun never sets upon the empire of the Queen of England. It has been caleulated, indeed, that she rules over an extent of territory *fifty* times as large as Great Britain, and over a population more than *six* times as numerous. Her *army*, exclusive of the native Indian troops, amounts to upwards of 100,000 men; her *navy*, to more than 500 ships of war, upwards of 100 of whieh carry from 72 to 120 guns each.

There are more than 30,000 *vessels*, measuring about 4,500,000 tons, and manned by upwards of 250,000 seamen, employed in the eommerce of Great Britain.

The *annual revenue* is nearly equal to a third of the sum total of the revenues of all the other European Kingdoms—amounting to about £50,000,000 sterling; but the *national debt* is enormous; it amounts to more than half of the debts of all the other European states put together—being nearly £800,000,000.

The national property is estimated to exeeed £3,700,000,000; the national ineome, or the produee from all kinds of industry and property, is said to amount to upwards of £500,000,000 a year.

I. ENGLAND.

HISTORICAL SKETCH.—England (whieh was aneiently Engle-land, or Angle-land, and means the land of the Angles,) was originally peopled, like all the middle, south, and

west of Europe, by the ancient *Celts*, who migrated in the earliest ages of the world from Asia, the cradle of the human race. It has been already mentioned that the Phœnicians traded for *tin* with the inhabitants of Cornwall, several centuries before the Christian era, but the history of Britain is buried in obscurity down to the 55th year before Christ, when it was invaded by the *Romans* under *Julius Cæsar*.

The Romans found the inhabitants a brave, but a rude and barbarous people, dwelling in hovels, and clothed in the skins of animals; from the savage custom of painting the exposed parts of their bodies, the Romans called them *Britons*, and the country, *Britannia*, or the *painted nation.* It took the Romans nearly a century finally to subdue this warlike nation, of which they kept possession till the commencement of the downfall of their empire, about the year A.D. 430.

The Romans introduced the arts of peace into Britain, and greatly advanced the civilization of the inhabitants; but these advantages were in those days counterbalanced by the effeminacy and decay of martial spirit by which they were accompanied, for when the Britons lost the protection of their conquerors, they were totally unable to defend themselves against the rapacity of their northern neighbours in Scotland.

About the year 449, they invited the *Saxons*, a warlike people from northern Germany, to their aid, but these no sooner expelled the Picts and Scots, which they did with ease, than they turned their arms against their allies the Britons, and seized the south-eastern part of their kingdom. Attracted by the accounts of the beauty and fertility of the country, numerous hordes of Saxons followed, and among others a tribe called *Angles* or Anglo-Saxons, who afterwards gave their name, Angle-land or England, to the country. These tribes of Saxons enslaved, expelled, or destroyed the original Britons. The greater part of those who were left the liberty of flight, either took refuge among the barren mountains of *Wales*, or fled to France, where they gave their name to the province of Bretagne, or Brittany.

The Saxons established what is called the *Saxon Heptarchy*, by dividing the country into *seven* independent kingdoms; these kingdoms lasted till the year 827, when they were united into one by Egbert, King of Wessex, who may therefore be called the first King of all England. Under the Saxon sway, the manners, customs, and language of the original Britons underwent a total change; all their national characteristics gradually merged into those of their rulers.

Between the years 866 and 1042, the DANES made many attempts, with various sucess, to gain possession of England. During the reign of Alfred the Great, their ambitious project was thwarted, and by the bravery and wisdom of that monarch they were finally expelled from the kingdom. But in 1017, 26 years after his death, they accomplished their object, under Canute the Great, King of Denmark and Norway, and took possession of the whole of England. The Danish dynasty, however, was but of short duration, for in 1042, on the death of Hardicanute, the son of the Conqueror, the Saxon monarchy was restored by Edward the Confessor.

On the death of Edward, in 1066, and under his will, William, Duke of Normandy, claimed the crown, but it was immediately seized by Harold, brother of the Queen. Between these two aspirants to the throne, the memorable battle of Hastings was fought, half a year after Harold ascended the throne; the result of which was, that Harold was completely defeated and slain, while the Duke of Normandy took undisputed possession of the kingdom, and was thereafter denominated William the Conqueror; and this event is known in English history, by the name of the Norman Conquest.

The effects of the changes which the Normans introduced into the manners, language, and laws of the Anglo-Saxons, remain visible to the most superficial observer at the present day; but this circumstance is the less remarkable, when we take into account the fact that the crown of England has been worn, ever since the Conquest, by the descendants of William, Duke of Normandy.

The following is a tabular list of the sovereigns of England since the Norman Conquest, the dates of their accession to the throne, the religion they professed, and a few of the most important events which have occurred:—

Date of Accessn.	Name.	Religion.	Important Events.
	Norman Line.		
1066	William the Conq.	Roman Catholic	Killed in an expedition against France.
1087	William Rufus	Do.	Wars against Scotland.
1100	Henry I.	Do.	Reign embittered by family broils.
1135	Stephen	Do.	Civil war. Right to throne disputed.
	Line of Plantogenet.		
1154	Henry II.	Do.	Ireland annexed to England.
1189	Richard I.	Do.	Crusades.
1199	John	Do.	Granted the Magna Charta.
1216	Henry III.	Do.	Civil broils.
1272	Edward I.	Do.	Subdued Wales. Executed Sir W. Wallace.
1307	Edward II.	Do.	War with Scotland. Defeat at Bannockburn.
1327	Edward III.	Do.	Protracted wars with France.
1377	Richard II.	Do.	Wat Tyler killed. King abdicates in fav. of Hen. of Lan.
	House of Lancaster.		
1399	Henry IV.	Do.	After quelling civil broils, reign peaceful.
1413	Henry V.	Do.	Much engaged in wars with France.
1422	Henry VI.	Do.	Was crowned king of France. War of the Roses of England.
	House of York.		
1461	Edward IV.	Do.	Civil discontent and insurrec.
1483	Edward V.	Do.	Crown usurped by bloody Richard of Gloucester.
1483	Richard III.	Do.	His bloody reign was short but cruel.
	House of Tudor.		
1485	Henry VII.	Do.	In him Houses of York and Lancaster were united.
1509	Henry VIII.	Became Protest.	Protestant Reformation. Henry declares himself head of the Church of England.
1547	Edward VI.	Protestant	Great confiscation and destruction of Church property.
1553	Mary	Roman Catholic	Married Philip of Spain. Religious quarrels.
1558	Elizabeth	Became Protest.	Mary Queen of Scots executed. Defeat of Spanish Armada.
	House of Stuart.		
1603	James I.	Protestant	Crowns of Scot. and Eng. united.
1625	Charles I.	Do.	The great civil war. King executed.
	Commonwealth.		
1653	O. Cromwell, Protec.	Puritan	Establishment of the Commonwealth.
1600	R. Cromwell, Do.	Do.	
	House of Stuart.		
1660	Charles II.	Nominal Protest.	The Restoration of the Stuarts to the throne.
1685	James II.	Roman Catholic	Revolution and abdication of King James.
	House of Orange.		
1689 till 1695	William III. and Mary II.	Protestant	War with France. Foundation of the National Debt.
	House of Stuart.		
1702	Anne	Do.	Victories of the Duke of Marlborough. Legislative Union between Scot. and Eng.
	House of Hanover.		
1714	George I.	Do.	Accession of the Ho. of Hanov.
1727	George II.	Do.	Adventures of Prince Charles Edward. American War.
1760	George III.	Do.	American War. French Revolution. Wars agt. Napoleon.
1820	George IV.	Do.	Emancipation of Catholics, of Greece, and of the Negroes.
1830	William IV.	Do.	Parliamentary Reform. Revolutions in France and Belgium.
1837	Victoria	Do.	Free Trade, Parliamentary and Educational Reform.

The length of England, from the coast of Dorsetshire to Berwick-on-Tweed, is about 360 miles; and its breadth from St. David's Head, in Pembrokeshire, to Lowestoff, in Suffolk, is about 300 miles. Its area is 58,320 square miles. The population in 1851, was 17,927,609; in 1841, it amounted to 15,906,741. For the ten years preceding 1841, the increase

was something more than 14 per cent. For the ten years preeeding 1831, the increase was 16 per cent.; and for the ten years preceding 1821, 17 per cent.

1. Superficial Features.—Although the country, in general, is either level or presents a gently undulating surface, it exhibits sufficient variety to render the landscape beautiful. Its western side is hilly or mountainous, while the eastern, sloping towards the German Ocean, becomes flat, and occasionally of a monotonous character. The *soil* in the midland, eastern, and southern counties, in particular, is rich and highly cultivated; in the north, there are some barren tracts; and several districts to the east are more or less covered by fens and marshes; but England is well entitled to be called a fertile, rich, and beautifully wooded country.

2. Climate.—From the insular position of England, there is an absence of extremes of temperature, but the climate is very humid, and there is almost incessant variations of temperature within a limited range. The average temperature of winter is about 40° Fahrenheit; in summer, the day temperature is about 60°, very seldom 80°. The prevailing winds are from the south-west and west, and the mean fall of rain for the whole island is about 36 inches.

3. Mountains.—England cannot be called a mountainous country; its western side, from Cumberland and Westmoreland, southwards through Wales, into Devon and Cornwall, is the only part of the country which can be called hilly. The chief mountains of England are the following:—

Names of Ranges.	Culminating Points.	Heights in Feet.	Position and Extent.
Devonian Range	Cowsand Beaeon	1,792	Extends fr. Bristol through Somerset, Devon, and Cornwall, and terminates in the promontory of the Land's End.
	Dunkerry Beacon	1,668	
	Rippon Tor	1,549	
	Brown Willy	1,368	
Cambrian Range	Snowdon	3,571	Extends through the middle of Wales, from north to south, from which spurs jut out on both sides.
	Plynlimmon	2,463	
	Llewellyn	3,469	
Cumbrian Range, or Pennine Chain	Scafell	3,166	Extends from the western extremity of the Cheviot Hills, on tho borders of Scotland, to the middle of Derbyshire.
	Helvellyn	3,055	
	Skiddaw	3,022	
The Cheviot Hills	Cheviot	2,658	Between Northumberland and Scotland.

4. Plains.—The plains of England are—(1.) The *Great Central Plain*, extending from Nottingham and Derby, on the north, to Oxford and Cambridge, on the south and south-east. (2.) The *Yorkshire Plain*, occupying a great part of Yorkshire, Durham, and Northampton. (3.) The *Eastern Plain*, comprising the counties of Norfolk, Suffolk, and Essex. (4.) The *Cheshire Plain*, extending through Lancashire, Cheshire, and Shropshire. And (5.) The *North* and *South Downs*, occupying a great part of Berkshire, Kent, Sussex, and Hampshire.

These plains are composed of *level tracts* of richly cultivated land, of *vales* and *marshes*. *Moorlands* are tracts of land, intervening between the hills and the level plains. The principal moorlands are those in Yorkshire—a wide, bleak, barren, and ungenial tract; those in Staffordshire, from 500 to 1154 feet above the level of the sea; Dartmoor, in Devonshire, covering upwards of 240,000 acres, extremely rugged, and 1700 feet above the sea level; Exmoor, partly in Devon and partly in Somerset, covering 20,000 acres, for the most part waste and irreclaimable; and the heathy uplands of Dorset, Hants, and Surrey.

The surface of England is much intersected by beautiful *vales*, or *dales*, composed of flowery meadows, clothed in the richest verdure, watered by copious streams, affording pasture to innumerable cattle, and presenting scenes of richness, fertility, and beauty, unsurpassed by any other portion of Europe. The principal *vales* are—the Vale of York, about 60 miles in length, and of variable breadth, covering a surface of 640,000 acres; Holderness, covering 270,000 acres, lying between the Humber and the sea, in the south-eastern part of Yorkshire; the Vale of Carlisle, covering 300,000 acres; the Vale of the Severn, extending through Gloucester and Worcester, for nearly 40 miles; the Vale of Exeter, covering 128,000 acres; the Vale of Taunton, covering 64,000; the *Wealds* of southern England; and the smaller *dales* of the Tyne, Wear, and Tees.

The low marshy district called the *Fens*, surrounding the Wash, and chiefly in Lincoln and Cambridge shires, although partly also in Northampton, Norfolk, Suffolk, &c., forms a level tract of not less than 400,000 acres.

5. Rivers.—The following are the principal rivers of England, the lengths of the most important, the direction in which they flow, the counties they pass through, their tributaries, and the chief towns on their banks:—

1. *Rivers falling into the German Ocean.*

Name and Direction.	Length in Miles.	Counties through which they flow.	Tributaries.	Chief Towns on their Banks
Tweed, N.E.	100	Is part of boundary between England and Scotland	The greater part is in Scotland	Berwick.
Tyne, E.	80	Northumberland, and part of it is the boundary between it and Durham	North Tyne and South Tyne	Newcastle.
Wear, N.E.	...	Durham		Durham and Sunderland.
Tees, E.	80	Between Durham and Yorkshire		Darlington and Stockton.
The Humber, E.	40	An arm of the sea between York and Lincoln	Ouse and Trent	Hull and Barton.
Ouse, S.E.	120	Yorkshire	Derwent, Wharfe, Aire, Calder, Don	York, Leeds, and Doncaster.
Trent, N.N.E.	144	Stafford, Derby, Nottingham, and Lincoln	Idle, Derwent, Dove, Soar	Derby, Stafford, and Nottingham.
Witham, N.E., S.E.	...	Lincoln		Lincoln and Boston.
Welland, N.E.	...	Northampton and Lincoln		Stamford.
Nen, N.E.	...	Do. Do.		Stilton.
Great Ouse, N.E.	150	Nottingham, Buckingham, Bedford, Huntingdon, Cambridge, and Norfolk	Cam, Lark, Little Ouse	Cambridge, Bedford, and St. Ives.
Yare, S.E.	...	Norfolk	Wensum	Norwich and Yarmouth.
Stour, E.	...	Between Sussex and Suffolk		Harwich.
Thames, E.	200	Between Oxford, Buckingham, Middlesex, and Essex, on the north, and Berks, Surrey, and Kent, on the south.	Charwell, Windrush, Kennet, Wey, &c.	London, Windsor, Reading, Oxford, Greenwich, &c.
Medway, N.E.	55	Surrey and Kent		Chatham, Maidstone, and Tunbridge.

2. *Rivers falling into the English Channel.*

Name and Direction.	Length in Miles.	Counties through which they flow.	Tributaries.	Chief Towns on their Banks.
South Avon, S.	...	Wilts and Hants		Salisbury.
Stour, S.E.	...	Dorset		
Exe, S.	...	Somerset and Devon		Exeter and Tiverton.
Tamar, S.	...	Between Devon and Cornwall		Plymouth.

3. *Rivers falling into St. George's Channel and the Irish Sea.*

Name and Direction.	Length in Miles.	Counties through which they flow.	Tributaries.	Chief Towns on their Banks.
Parret, ...N.W.	...	Somerset	....	Bridgewater.
Severn, ...S.W.	190	Montgomery, Salop, Worcester, and Gloucester..........	Wye, Teme, Avon, Lower Avon....	Shrews. Wor., Glou. Bath, Bris., &c.
Dee, ...N.	...	Merioneth, Denbigh, Cheshire, Flint........	....	Wrexham, Chester, and Flint.
Mersey, ...W.N.W.	62	Between Cheshire and Lancashire	Weaver........	Liverpool.
Ribble, ...S.S.W.	...	York and Lancashire	....	Preston.
Eden, ...N.W.	72	Westmoreland and Cumberland........	....	Appleby and Carlisle.

6. Lakes.—The "Lake District" of England is situated in the north, in the counties of Cumberland, Westmoreland, and Lancashire; and although the lakes are mere pools compared to the large sheets of fresh water which are found in many other parts of the world, yet the picturesque beauty of the surrounding scenery, the Alpine wildness of the Cumbrian range of mountains among the vales and recesses of which they are placed, the mirror-like stillness of the waters, their beautifully wooded banks, clothed in the richest verdure—all combine to lend an enchantment to the English lakes, which is denied to many more extensive and more celebrated inland sheets of water. The largest of these lakes scarcely covers an area of four square miles. The chief lakes are the following:—*Windermere*, between Westmoreland and Lancashire; *Ullswater*, between Cumberland and Westmoreland; *Derwentwater*, or *Keswick Lake*, in Cumberland; *Thirlmere*, *Bassenthwaite*, *Buttermere*, and *Cumnock-water*.

7. Bays, Gulfs, Straits, and Sandbanks.

(1.) The *Bays* and *Gulfs* are—

Bridlington Bay—in the east of Yorkshire, near Flamborough Head.

Humber Mouth—an estuary of the sea between Yorkshire and Lincolnshire.

The Wash—a large shallow inlet, full of sandbanks and mud shoals, between Lincolnshire and Norfolk, draining about 5000 square miles of country.

Yarmouth Roads—on the east coast of Norfolk.

Blackwater Bay—on the coast of Essex.

Mouth of the Thames—an estuary encumbered with numerous intricate shoals and sandbanks,

The Nore—near the mouth of the Thames, off Shearness.

The Downs—between the coast of Kent and the Goodwin Sands.

Spithead—between Hampshire and the Isle of Wight.

Southampton Bay—at the head of which is the town of Southampton.

Poole Harbour—on the coast of Dorsetshire.

Torbay—on the south-east coast of Devonshire.

Plymouth Sound—celebrated for the stupendous breakwater, which protects its water from the swell of the Atlantic.

Mounts Bay—in the south of Cornwall; its name is derived from St. Michael's Mount, a curious rock a little off the mainland.

Barnstaple Bay—on the north-west coast of Devonshire.

Bristol Channel—between Somerset and Glamorgan; a deep gulf, 25 miles wide at its entrance, and about 8 where it joins the estuary of the Severn.

Swansea and Caermarthen Bays—on S. W. coast of Glamorgan and Caermarthenshires.

Milford Haven—on W. of Pembrokeshire; one of the safest and most capacious harbours of England.

The large Bays of Cardigan and Caernarvon—W. of Cardigan, Merioneth, and Caermarthenshires.

The Estuary of the Dee—between Cheshire and Flintshire.

Liverpool Bay—on the coast of Lancashire, at the mouth of the Mersey.

The Estuary of the Ribble—on the west coast of Lancashire.

Morecombe Bay—in N. W. of Lancashire; a large inlet, so shallow that proposals were at one time made to reclaim it from the sea.

Solway Frith—between Cumberland and Scotland.

(2.) The *Straits* are—

The Straits of Dover—between England and France; 21 miles across, and about 17 fathoms at its greatest depth; there is now an Electric Telegraph connecting England with France, deposited at the bottom of this strait, in a tubular rope of iron wire of great strength.

The Menai Strait—separating the island of Anglesea from the mainland of Wales; it is about 14 miles in length, and varies from 2 miles to 200 yards across. It was looked upon as a great feat when this strait was crossed by a splendid suspension bridge, erected by Telford in 1826; but a much more stupendous feat has been accomplished by Stephenson in 1851, in crossing it by a magnificent railway tubular bridge.—*See Frontispiece of this work.*

(3.) The *Sandbanks* are—

Dogger Bank—in the German Ocean, between the mainland of Yorkshire and Jutland.

Goodwin Sands—on the east coast of Kent.

8. Capes.—The Capes of England, commencing on the Yorkshire coast, are the following—

Flamborough Head, and Spurn Head—in Yorkshire.

North Foreland, South Foreland, Dungeness—in Kent.

Beechy Head—in Sussex.

Needles—on the west of the Isle of Wight.

St. Alban's Head, and Portland Point—in Dorsetshire.

Start Point, and Bolt Head—on south coast of Devonshire.

Lizard Point, and Land's End—in Cornwall.

Hartland Point—on north-west coast of Devonshire.

St. Goven's Head, St. David's Head, and Strumble Head—in Pembrokeshire.

Holyhead—in Anglesea.

Ormes Head—in Denbighshire.

St. Bee's Head—in Cumberland.

Air Point—in the Isle of Man.

9. Islands of England.—The islands on the coast of England are, with few exceptions, very small and unimportant. The principal, beginning at the north-east extremity, are the following:—

(1.) *Off the East Coast.*

Holy Isle, or Lindisfarne—containing the remains of an Abbey and Castle; off Northumberland; 9 miles in circumference; population, 908.

The Fern and Staples Isles—two dangerous groups of small rocky islets, off Northumberland. Pop. 20.

Foulness and Sheerness—at the entrance of the Thames.

The Isle of Thanet—a district of Kent, formed by two branches of the small river Stour. It contains two great watering places, Margate and Ramsgate.

(2.) *Off the South Coast.*

The Isle of Wight—a large and beautiful island. In its centre is Carisbrook Castle, where Charles I. was confined. It is a frequent resort of our present Queen, who has a royal residence there, called Osborne, near Cowes. Pop. 50,324.

Purbeck and Portland Islands—off Dorsetshire, noted for their freestone quarries.

Eddystone Rock—a reef of rocks in the English Channel, 14 miles S. W. from Plymouth; on the highest rock is the celebrated lighthouse, erected by Smeaton in 1759.

The Scilly Islands—a group of 17 rocky islets, only 6 of which are inhabited; they lie 30 miles west-south-west

from the Land's End. The largest is St. Mary's. Total pop. 2,627.

(3.) *Off the West Coast.*

Lundy, Skomer, Bradsey, Holyhead, and the Skerries—small and unimportant islands, with the exception of Holyhead, off Anglesea, in which is a thriving seaport, from which the Irish packets sail. Pop. 5,622.

Anglesea—a large island and county of Wales, joined, as already stated, to the mainland by the Menai suspension and the Britannia tubular bridges. It is celebrated for its rich mines of copper and lead, and as being an ancient seat of the Druids. Pop. 57,327.

Isle of Man, anciently *Mona*, is a large island in the Irish sea, which legislatively and judicially forms a sort of independent territory. It is 20 miles from the coast of Scotland and nearly equidistant from England and Ireland. Pop. 52,387.

The Channel Islands, Jersey, Guernsey, Alderney, and Sark, near the coast of France, have been already noticed among the islands of Europe.

AGRICULTURE.

CHAPTER IX.

MANAGEMENT OF A FARM DURING SUMMER.

Although the farmer during summer is busy enough, yet in it he gets his only holiday. There is little on the farm that requires his general superintendence, from the end of the hay harvest to the commencement of the corn one. The hours kept by the ploughmen and horses vary in different localities of the red sandstone districts of Scotland. A very common arrangement of time is to begin at six o'clock, work till eleven, rest till one, and work till six. Sometimes the rest is extended until two o'clock, and in this case, but not always, the labour is prolonged until seven.

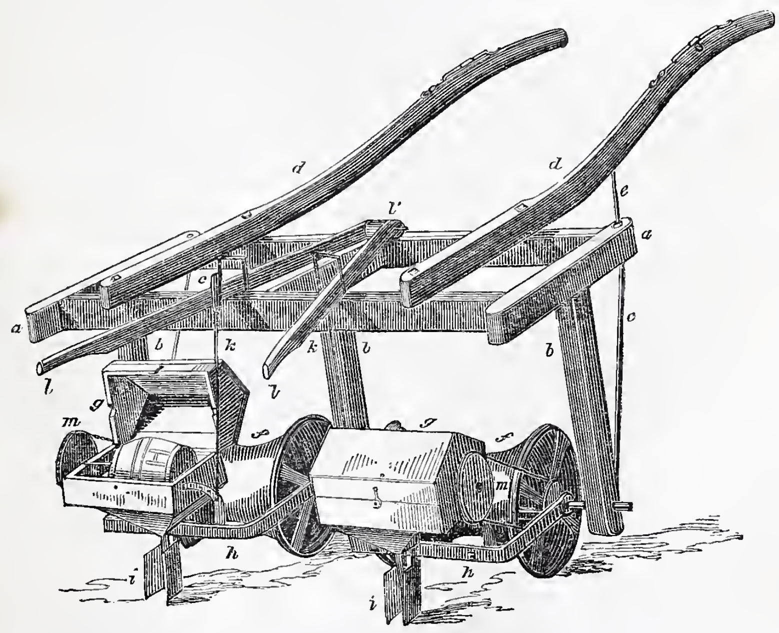
TURNIP CULTURE.

This is the basis of successful farming. When a good crop of turnips is seen upon a farm, we may be sure that all the rest will be good, and *vice versâ.*

The land is prepared in the same manner as for potatoes; ploughed, grubbed, harrowed; set up in drills—the drills are split; dung, and whatever other manure is used, placed in them; then they are covered in, and are ready for the reception of the seed. As in the case of potatoes, these drills are made twenty-seven inches apart.

The seed is then deposited in these drills by means of a very efficient implement—the turnip-sowing drill. Sometimes, along with the seed, bone-dust is sown; but the best manner of sowing bone-dust, guano, or any portable manure, for land intended for drill crops, is to sow it broadcast after the drills are split, and before the dung is covered in. The roots of the plants extend from drill to drill, and the more the manure is diffused, the more readily is it taken up by them.

One of the most efficient and simple sowing drills, which sows seed alone, is the East Lothian turnip-drill. The annexed figure is a view in perspective, in which the horse shafts, *d d*, are bolted to the bed-frame, *a a*, supported by stay-braces, *e, e*, and furnished with the usual horse mounting. This machine sows two drills at a time, and to support it upon two of the drills of land, two rollers, *f f*, which are both motive and compressing, are provided, one for each drill, and so curved longitudinally as to embrace the upper part of the drills, and revolve upon a shaft passing through the lower ends of the upright



The East Lothian Turnip-sowing Drill.

bars, *b*. Of the two seed-boxes, *g g*, one is shown thrown open, and they are attached to the iron bows, *h h*, through the ends of which the axle also passes, whereby the whole becomes moveable upon the axle. The bottom of the boxes is formed funnel-shaped, terminating in a nozzle which passes between the sheathes, *i i*, of the coulter for conveying the seed from the boxes to the ground: the bottoms of the boxes are firmly attached to the bow, *h*. Connecting rods, *k k*, are attached to the seed-box frame, for regulating the depth of the coulter in the soil. The seed-barrels are mounted on axles within the box-frame, *g*, the outer extremity of which is furnished with a pulley, *m*, corresponding to another fixed in the end of the roller, *f*, and both made to move by means of a jack-chain. The handles, *l l*, move upon the joint, *l'*, and, when elevated, draw the coulters, *i i*, out of the ground, and when depressed by the weight of the hand, keep them steady in the ground. An important function of this machine, is its self-adjustment to the width of the drills, which is accomplished by the width between the pendants, *b b*, being greater than the length of the rollers.

The Swedish turnip is sown not later than the end of the second week in May, and 3 lbs. of seed are employed to the acre. The yellow is begun to be sown when the sowing of Swedish is completed, and the white turnips are sown from the beginning to the end of June. Of both these latter kinds, $2\frac{1}{2}$ lbs. of seed per acre is sufficient.

If it is warm weather, with occasional showers, the young turnips may be expected to make their appearance in the course of about a week; but if the weather be not favourable, they will be longer. When the plants have attained a height of about 3 inches from the ground, they are *singled*, as it is called.

The first step in this operation is to run the horse-hoe between the drills. The effect of this is partly to loosen the earth, but principally to undercut all the weeds that exist between the drills, a purpose that it very effectually, at least in recently clean land, performs. The horse-hoe is only drawn by one horse, and hence the ploughman has it in his power to give one of his horses, that may be out of order, a day's rest, or he can work one in the morning and another in the afternoon. As the shares of the hoe run almost close to the young turnips, horse-hoeing is a very nice operation, and it requires a steady horse and a careful man to avoid coming against the young crop.

The field labourers then, with hand-hoes, single the turnips. The white turnips are made to 9 inches apart, the yellows 10, and the Swedes 11. The following table, abridged from Stephens, shows the crop per acre, as it may be ascertained by weighing one. It would indicate that, owing to bad singling, a far less crop than might be obtained is usually got. It assumes that the distance between the drills is 27 inches:—

Distance between the Plants.	Number of Turnips there should be per acre.	Weight of each Turnip.	Weight which the Crop should be per acre.	
			Tons.	Cwt.
9 inches	25·813	1 lb.	11	$10\frac{1}{2}$
		2 lbs.	23	1
		3 lbs.	34	$11\frac{1}{2}$
		4 lbs.	46	2
		5 lbs.	57	$12\frac{1}{2}$
		6 lbs.	69	3
10 inches	23·232	1 lb.	10	7
		2 lbs.	20	14
		3 lbs.	31	8
		4 lbs.	41	8
		5 lbs.	51	15
		6 lbs.	62	2
12 inches	19·360	1 lb.	8	$12\frac{3}{4}$
		2 lbs.	17	
		3 lbs.	25	$18\frac{1}{4}$
		4 lbs.	34	11
		5 lbs.	43	$3\frac{3}{4}$
		6 lbs.	51	$16\frac{1}{2}$

As single turnips may certainly be made to attain more than the highest of these weights, and as these large crops are not obtained, it would appear that, mainly owing to careless singling, a large quantity of what would be crop is lost.

Each field labourer can single about half an acre a day.

After the singling, the horse-hoe is again run between the drills, and then the field-workers free the ground between the plants, to destroy the weeds, and to loosen the soil. After-weedings and horse-hoeings may be necessary, and some are always given. Many farmers set up the drills with a double mouldboard plough, but this is now considered bad farming, as it destroys many of the roots of the crop.

PASTURING CATTLE, SHEEP, AND HORSES.

Formerly it was the custom to pasture all the animals of a farm during summer, but it is found that soiling, *i. e.* cutting them their food, and giving it to them in their houses, is far superior. Animals, it is found, when pasturing, destroy as much food as they eat by tramping; that is to say, while it requires one acre to pasture an ox, half a one will soil him, and the dung, a great portion of which is lost in pasturing, is all preserved. But, in practice, a thorough system of soiling is found impossible. When the grass is short, the saving does not equal the expense of cutting, and, moreover, it is found difficult to procure litter. Besides, during the very extreme of summer, the animals are healthier when sleeping out of doors. The plan that is now considered the best, seems to be to pasture the sheep, and to part pasture and part stall-feed cattle and horses.

It is necessary that all pasture fields should have a due supply of water, and sheds, or other shelters, where the animals can retire from the extreme heat of mid-day.

SHEEP SHEARING.

Preparatory to the sheep being sheared, they are bathed in water to rid their fleeces of some of the impurities sticking to them. If possible, a pool is made in a natural rivulet, by erecting a dam-head across it. The sheep intended to be washed are brought to one side of it, to an enclosure, which is surrounded by nets. The shepherd and his assistants have on a pair of old trousers, old shoes, and a shirt with the sleeves turned up to the shoulders. Unless the stream is very strong, he has two assistants in the water with him, and one standing on the bank where the sheep are, to hand them into the pool. The washing is managed as follows:—A sheep is caught and handed to the first washer, who is standing up to his middle in the stream. He holds the sheep on its back, taking care to keep its head up, and moving it from side to side. The water becomes very turbid from the dirt contained in the fleece, and he continues his labour until it becomes less so. He then hands the sheep to washer No. 2, who is standing in the middle of the stream a yard or two higher up, so as to insure a supply of clean water. He washes the animal over again, and hands it in his turn to the shepherd, who is standing near the bank farthest from where the unwashed sheep are, and a yard or two higher up the stream than the second washer. The shepherd examines the sheep, and if he thinks it clean enough, passes it, and if not, completes the washing himself.

The shepherd, with his three assistants, will, in this manner, wash fifty or sixty sheep in an hour.

After having been washed, the sheep are put into a grass field to dry. Before it has become thus thoroughly dry, and before, too, which is necessary, the wool has got saturated again with oil or yolk (which the washing takes out), eight or ten days usually elapse. When this is done, it is time to shear the sheep.

This shearing of sheep is very hard labour. It is performed by means of shears, and by experienced workmen, without inflicting any injury upon the animal; but beginners seldom fail to mangle the poor animals they first operate upon. The operation, when skilfully performed, is a very pleasing one, and the passive manner in which the sheep remain still is very extraordinary. But it is not easy to describe it in words.

It is considered very good work to shear twenty-five sheep in a day.

After the fleeces are shorn, they are rolled up by a field labourer, and stored in the wool-house until either a woolstapler comes to inspect and make offers for them, which used to be the common plan, or until, which is now getting to be the custom, they are sent to a commission agent to sell for the farmer.

HAYMAKING.

In the districts, to the agriculture of which we principally confine our remarks, because in general their culture and management is the best of any, haymaking is almost uniformly wretchedly managed. The grass is cut far too late, allowed to blanch in the sun, to have its soluble part washed out by the rain, and to become partially rotted by the growth of the aftermath. It is then put in large cocks or ricks up and down the field, for the purpose apparently of destroying those parts of the aftermath upon which it is placed, and which purpose it most effectually performs. The withered blades of grass are then put together into a stack, and constitute what a Lothian farmer, but certainly not an English one, calls hay.

The following is an outline, not of the bad mode of hay-making, but of the method followed in the midland counties of England, and, very probably, over the whole of the southern half of Great Britain. It should be observed, however, that English hay usually consists of more grasses than the ryegrass and the clovers of the Scotch.

The proper time for beginning to cut the grass is before its seeds are at all ripened. It is always cut with the scythe, and of all scythes the Hainault one, for this and for other purposes, is the best. The scythe is kept sharp by the use of the shukle and the scythestone. It is common to let the mowing to labourers by the acre; and the field-workers (*i. e.* the male ones), at this season and at harvest, expect to make more than their usual wages by a good deal. Last year, in the Lothians, the usual sum was half-a-crown an acre. The writer of this had one year a small grass field in England, and paid for the mowing of it either four shillings or four shillings and sixpence an acre; but being there as a mere bird of passage and a stranger, he was probably imposed upon. A man can mow an acre in a day. The Englishman who did the small field of the compiler's did nearly two, but he worked very hard, and nearly the whole of the night.

The cut grass is deposited by the scythe in rows or swaths. In the part of England with which the writer is familiar, a worker follows the mower with a fork, and at once scatters the new-mown grass over the whole ground where the grass has been cut. In favourable weather it is soon turned and returned, and arranged into swaths. These swaths are turned and rolled into small cocks or ricks, each containing perhaps one or two stones of hay. Several of these are rolled together to form large ones, and often, in the course of two or three days, the whole are led away and formed into a stack.

During the whole of these processes, the hay is very much shaken and exposed to the sun and wind, and its moisture allowed to evaporate. Upon many farms, instead of being done by hand, it is effected by a machine—the hay-tedding machine—which performs its purposes very effectually.

After the hay has been in the stack some little time, it becomes very hot, and also very moist. To this process, which lasts some days, the name of *sweating* is given. Of the real nature of the change effected, we regret to say that we are quite ignorant; but it would appear that some change takes place in its composition, by means of which its fragrancy and aromatic principles are increased, and its bulk is diminished from its having become more compact.

SUMMER CULTURE OF THE CEREALS.

This is much the same for wheat, barley, and oats, but we may give each a passing notice.

Wheat is but too apt to become foul with weeds, of which, perhaps, the corn-cockle is the most troublesome. If the wheat is sown broadcast, all these weeds must be removed by manual labour. The workers, to eradicate the cockle, which has a woody stem, employ their hands; but for the smaller they take a little implement, called a weed-hook, that expedites their labour. When the land is drilled, it is cleared by speared horse-hoes invented for the purpose. These have usually from six to a dozen hoes, and are very useful. They require, however, to be worked both by steady labourers and steady horses.

The weeds of barley are eradicated in the same manner as those of wheat.

Oats require weeding sooner than either of the other two, and are sometimes disagreeably pestered by the creeping plumed thistle. It is recommended not to cut this until it has attained a height of about nine inches, as otherwise it will spring up again.

SUMMER CULTURE OF POTATOES.

After the potato plants have attained three or four inches in height, a horse-hoe is passed between the drills to destroy the weeds, and the potatoes are then carefully hand-weeded and hoed, and this last process is repeated as often as necessary. They are then set up with the double mould-board plough, for the purpose of preventing any tubers being found above ground. If such be allowed to form, they are neither wholesome nor matured, but green and bitter.

A notion has been recently promulgated, that it is proper to cut off the flowers of potatoes upon the ground—that this, preventing the strength and substance of the plant being thrown into the blossom, will increase the number of the tubers. Whether this is the case or not, it is not easy to say; but as it is not done in actual practice, we may infer that the farmers are of opinion that it is rather unfounded, or that the advantage to be derived from it is not equal to the labour that it would entail.

SKETCH OF THE METAL MANUFACTURES.

I.—IRON.

INTRODUCTION.

Mr. Warington W. Smyth, in opening the course of Mineralogy and Mining, in the Government School of Mines (November, 1851), remarked that "the prime and grand interest attached to our studies of the products of the earth is to be found in the fact, that the mineral properties of different lands, in conjunction with their geographical features, have determined the distribution, the physical and social character, and the well-being of the various races of man. Whether we examine the vestiges left by the peoples of gray antiquity, or study the modifications produced in branches of the same race located in regions of different aspect, or inquire into the origin of the chief seats of modern civilization, we shall be assured that most of these phenomena are dependent immediately, or through the medium of vegetation, on mineral produce, and the particular conditions under which it can be made available to human convenience. In the remains of ancient Egypt we learn how a stupendous architecture arose by the aid of the soft yet massive sandstones piled by nature on the banks of the Nile, and how monolith statues and obelisks were suggested by the presence of a syenite capable of taking a high polish, and admitting of the sharpest intaglio tooling. In Attica, the marble of Pentelicus and the silver of Laurion combined to develop that high state of art which, exemplified in the Parthenon and the sculptures of Phidias, has never since been equalled; whilst the abrupt limestone ravines of Lycia and Arabia Petræa gave rise to a description of architecture peculiar to itself. As examples of the second point, call to mind the different occupation and character of the dwellers in the Spanish peninsula,—the active mining and mercantile population of Gallicia, Asturia, and the Basques on one hand, the indolent Castilian and Portuguese on the other. Or compare the torpid millions of the Slavic race in the plains of Russia, with their industrious relatives and co-religionists in Servia and Bulgaria. Lastly, in furtherance of the third inquiry, we need only to examine the beautiful population map of the British Islands, by Petermann, which shows at a glance that, besides the conditions requisite for the purposes of shipping, it is coal and iron, and lead and copper, that mainly influence the increase of our towns. Nor can we omit to refer to the amazing process by which the discovery of gold is at this day pouring a new tide of population over parts of Siberia, to Western America, and to the Antipodes."

It has often been made subject for consideration—to what circumstances does this country owe the high commercial and national position which it has attained? The coal, the metallic riches, the insular position, the steady industry, the inventive talent, the commercial probity and honour, the maritime power, the facilities for intercommunication—all have been cited in turn as causes of this greatness. But a more thorough comparison of ourselves with other nations, on these and other points, will be necessary before just conclusions can be formed. It is probable that all the advantages here enumerated, and many additional ones, contribute to the production of the grand result; but the effective value of each, disentangled and separated from the rest, few, if any persons, are yet in a condition to determine. We shall have to curb down national vanity a little, and to collect the opinions of intelligent

foreigners, such as Dupin and Kohl, as a means of correcting our own, before we can place the estimate on a right basis.

That which cannot be stated with precision, however, may be expressed in general terms. There can be no doubt whatever that *one* of the causes for this country's greatness is the rich supply of METALS which lies within the bosom of the ground. The tin, the lead, the iron, and the copper, forming the four chief varieties of English metals, are in exhaustless abundance, and have for ages afforded the rough material whence so many of our productions are formed.

The raw mineral produce of Great Britain and Ireland (including coal) is valued at not less than £24,000,000 per annum, or about four-ninths of that of all Europe, including these islands. The following table exhibits the comparative amount of the mineral produce of the different European states, that of Great Britain being represented by unity:—

Great Britain,	1	Hartz,	$\frac{1}{12}$
Russia and Poland,	$\frac{2}{7}$	Tuscany,	$\frac{1}{31}$
France,	$\frac{1}{4}$	Bavaria,	$\frac{1}{33}$
Austria,	$\frac{2}{13}$	Saxony,	$\frac{1}{34}$
Spain,	$\frac{1}{8}$	Piedmont and Savoy,	$\frac{1}{38}$
Prussia,	$\frac{1}{9}$	Denmark,	$\frac{1}{49}$
Sweden,	$\frac{9}{19}$	Norway,	$\frac{1}{55}$

"With regard to iron," remarked Sir Henry De la Beche, in his inaugural discourse, on the opening of the School of Mines, "Great Britain has made remarkable progress within the last century. In 1750, only 30,000 tons of that metal were raised in it. In 1850, 2,250,000 tons of iron were produced. It is somewhat difficult, by means of official returns, to obtain the exact equivalent in tons of pig-iron exported, but we find the value of the iron export in 1849, including pig and bar iron, iron wire, and various kinds of wrought iron, taken at £4,245,049. Iron, therefore, of many millions in value remains for our home consumption, applied in various ways to our national industry. Tin should not be omitted as among our important British metals, seeing that it is raised to the amount of about £400,000 annually; neither should our copper be forgotten, since that of Cornwall and Devon alone may be valued at nearly £900,000 annually. With regard to copper and tin in that district (British tin is alone found there), of the former it yields one-third, and of the latter nine-tenths of the whole supply from the remainder of the British Islands and all the other countries of Europe. As to tin, the quantity taken from Cornwall and Devon from the time of the Phœnicians must have been enormous, seeing that until of late years it seems to have supplied nearly the whole of the European demand."

To give a rapid glance at the manufacturing history of these metals—iron, tin, lead, and copper—is the object of the following chapters. Those which enter most largely into consumption will be traced from the mine to the workshop; and their application to a few among the countless purposes for which they are fitted will come under notice. Iron will, for obvious reasons, occupy more of our attention than any other metal. It need hardly be said that the broad features can alone be touched on in this limited space.

CHAPTER I.

THE MINE, THE FOUNDRY, AND THE FORGE.

Among the various manufacturing establishments which our country exhibits, there are few so important, so interesting to a stranger, and conducted on a scale of such great magnitude, as the more distinguished iron-works. Whether we go into South Wales, Shropshire, or South Staffordshire, into Derbyshire or the West Riding of Yorkshire, or into the district of Scotland lying around and eastward of Glasgow, we find these smoking, fiery, ever-active works; where the precious metal iron (more precious by far than gold or silver in relation to the prosperity of a country) is extracted from the crude ore found beneath the soil. If the geological character of these districts be examined, it will be found that the iron ore itself, and the coal which is necessary for smelting it, are found lying in beds or seams near each other; and that, in some of the British mines, not only may coal and iron ore be dug out of the same pit, but they are actually combined in the same seam or bed. Some of these establishments have the iron ore beneath them, so as to combine all the operations at one spot; while in others, the ore has to be brought from a distance to the works.

On approaching a large iron-work, the flame and smoke of the blast furnaces vividly point out the locality. This ever-enduring flame is one of the most remarkable features of all such works, and is in Staffordshire especially observable, from the large number of furnaces there congregated. An iron furnace is a most untiring laboratory—it works night and day, Sunday and week-day, never stopping an instant for months, or perhaps years, together; it is always nearly full of fiercely burning materials, and is replenished at the top as fast as the product is drawn out at the bottom; and its top being generally open to the air, a vivid body of flame is almost continuously shooting upwards, visible for many miles in every direction.

Perhaps our object will be best attained by briefly describing the arrangements at some one of the works where the mining is conducted, as well as the smelting. We will therefore take a large establishment in one of the midland counties of England as a type of the rest.

At the works which we have in view, there is an area of many acres filled with various buildings incidental to the manufacture of iron. Of these the most important are three large blast furnaces, with all the arrangements for producing either the *hot blast* or the *cold blast*. In some of the larger works there are eight or nine of these furnaces. Those who have not seen a smelting furnace (for they are called indifferently "blast" or "smelting" furnaces) have but little idea of their appearance. They are huge and clumsy erections, formed so as to possess great strength and great power of resisting heat. In some instances they are conical, like a glass-house; in others, they are nearly cylindrical; in others, again, they have a square horizontal section, and partake in their general appearance and construction much of the character of Egyptian buildings, especially in the opening which forms the lower mouth of the furnace. The furnaces are from forty to fifty feet in height; they are built of stone quarried in the neighbourhood, and are lined internally with fire-bricks and cement capable of resisting heat.

Fig. 1 is a front view of a blast furnace, as commonly constructed in this country, although it may exhibit in different localities slight modifications of form. F is the body of the furnace, A is the lower mouth or door, and O an opening, or one of a series of openings, at the top for introducing the ore and fuel.

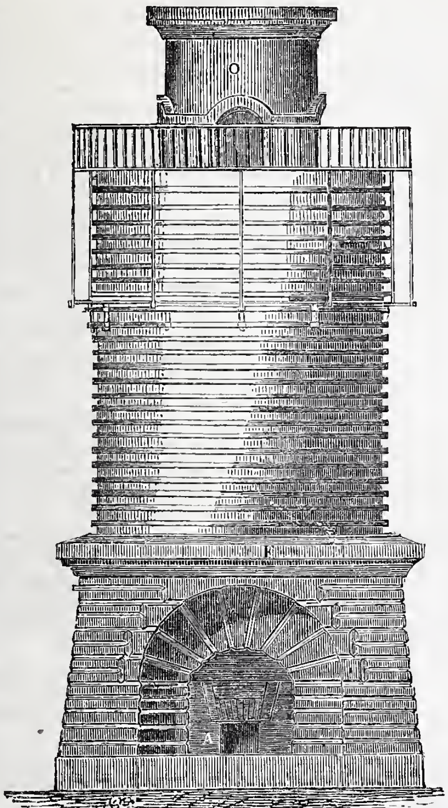
All the three furnaces in those works to which we have alluded, are bounded on the eastern side by an embankment nearly as high as the furnaces themselves; and the surface of the embankment presents itself as a nearly level road, terminating at the furnaces at one end, and at the mines and collieries at the other. This arrangement, as we shall hereafter explain, affords great facilities for filling the furnaces. Near this embankment is a lengthened area occupied by an enormous heap of ironstone undergoing the preparatory process of roasting; some thousands of tons being thus strewed over the place.

In front of the furnaces are all the busy and remarkable arrangements for casting the melted iron into sand moulds. A very large roofed shed extends in front of the mouth of each furnace; and the floor of this shed or foundry has in it various earthen pits in which to make large castings; together with cranes for raising and shifting ponderous vessels filled with the melted iron. If these places be visited about four in the afternoon (or, perhaps, rather at four in the morning, at which hours the furnaces are emptied of their liquid metal), the glare of light thrown around from the mouth of the furnace on the swarthy persons of the workmen, as well as on the dark roof and walls, together with the current of white hot liquid metal as it flows to the moulds, presents a very striking scene. If one of our distinguished painters in oil (for plain black and white cannot represent such a scene), would condescend to

visit an iron-foundry at such a time, and transfer to his canvas what meets the eye, he might produce a picture in which the play of light and shade would be remarkable enough, and might at the same time convey an idea of the warm work to which furnace-men are exposed.

Beyond and around the furnaces and their foundries are various other buildings pertaining to the manufacture of pig

Fig. 1.



and cast iron; and the greater part of the remainder are occupied by engineers and machine-makers.

On the level of the embankment, which commences near the top of the blast furnaces, there is a line of railway extending eastward. This railway is in connection with others, branching off at various points, and in different directions; the length and number of these branches being such, that there are nearly twenty miles of railway on the whole works. There are two large clusters of buildings, situated far apart—one for smelting and casting, the other for smelting and forging; and in the intervening districts are the coal and iron mines. As the seams of coal and ironstone extend beneath the whole district, there have been numerous pits sunk for the extraction of these valuable materials. These may, in fact, be considered as so many distinct establishments; each colliery being under a distinct manager, who has under his care several pits or shafts, a large number of steam-engines, a body of miners, and all the arrangements for conveying the produce from the works. Each colliery, or establishment of this kind, has a distinct name by which it is known. One of these has twelve ironstone pits or shafts, five coal-pits, a steam-engine of seventy horse power, for pumping the water from the mines, and eleven other steam-engines of smaller power, for raising the miners and the materials from the pits. All the other collieries scattered over the district resemble in their general features this one. The mode of descending the shafts is very convenient and expeditious. The shafts are lined cylindrically with brickwork, and there is an iron platform which nearly fits each, and which travels from top to bottom nearly as a piston would in a cylinder. The miners stand on the platform, which is suspended by a flat rope made of iron wire (one of the improvements of modern times), and a steam-engine lowers them all with swiftness and regularity to the bottom, a depth (in some of the pits) of five or six hundred feet. The various galleries of the mine, extending horizontally from the bottom of the shaft, are arched passages of the usual character, but tolerably clean and free from water. The various labyrinthine passages belonging to the different collieries form a network, extending beneath an area of about six square miles in extent.

There is another interesting feature in the district; for wherever there is coal fitted for making *coke*, a new branch of trade may be established, deriving great importance from the extensive use of coke in locomotive engines. The employment of coke in smelting iron is, as we shall explain further on, not now so general as it has been; but the smelters, after supplying their own wants, have established a large sale of coke from this spot. The appearance of the coke-work is altogether singular. On ascending the inclined plane, a range of about a hundred coke-ovens is seen, lying somewhat in horse-shoe form. Each oven is a brick structure eight or ten feet high, having a flat roof, with an opening at which to introduce the coal, and another opening in front, at which to remove the coke. All being arranged contiguous, there is a railway running along the roofs of all of them, at a distance of two or three feet from the charging holes. There is a colliery close to the ovens; so that the coal is no sooner drawn up to the mouth of the pit, than it is wheeled along the railway and emptied into any one of the ovens. In these ovens the coal is kindled without access of air, and is deprived of its bituminous and more inflammable ingredients by the usual process of coking. When the coke is removed from the ovens, and ready to be taken away from the works, it is placed in carriages on the railway, and, by an ingenious arrangement of ropes, is allowed to descend the inclined plane to the canal by its own weight, drawing up, at the same time, a train of empty carriages to be refilled.

How the various parts of such an establishment as this are brought to bear one on another, may next engage our notice. In the first place, then, it will be necessary to show from what iron is made, and how it is found. Is it found pure or earthy, heavy or light, moist or dry? Is it found in small pieces or in large layers; deep in the ground or near the surface? Such questions are very likely to occur, and deserve a clear answer.

The iron ores proper are divided into native iron; oxides, carburets, sulphurets, arseniurets, and phosphurets of iron; chlorides, sulphates, phosphates, and titanates of iron. The deposits of native iron in any part of the world are very limited; it has been found in Connecticut, United States, in a vein or plate two inches thick, and sufficiently ductile to be wrought into nails by a blacksmith. It was found in a mica slate rock, upon a primitive mountain, and very much intermixed with plumbago. Native iron has also been found in France and Germany; but there are serious doubts whether it is formed by nature. Its existence may, perhaps, be assigned to the previous burnings of stone coal in its vicinity. We mention it, therefore, chiefly as a matter of curiosity, not as an article of manufacturing importance. The oxides of iron, especially the loadstone, or magnetic black oxide of iron, constitute the most important class for the manufacture of iron in the United States. In England and Scotland, the carbonate of iron is the principal ore from which the metal is smelted, and yields usually from thirty to thirty-three per cent. This comprehends most of the clay ironstones of the coal measures, and scarcely any other kind is wrought in this country.

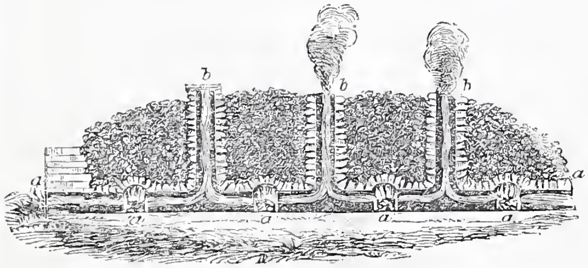
In this form the metal is found combined with various earthy substances in a stony dark-coloured ore called *ironstone*, which ore differs in different districts, some containing a larger per centage than others of pure iron, some containing clay but no lime, some lime but no clay, some holding a small quantity of coal, while others have none; but nearly all containing water, silex or flint, sulphur, and carbonic acid. The ore occurs

in beds of varying thickness, from a few inches to several feet; and as the beds are generally inclined to the horizon, there are parts where they 'basset' or 'crop' out at the surface, while at other parts the bed may be many hundred feet below the surface. There are generally a great many beds or seams, one beneath another, separated by beds of other mineral; and in all such cases every bed has a local name applied to it, such as the 'tan-yard,' the 'cement,' the 'black,' the 'blue,' the 'old man,' the 'whetstone,' the 'wallis,' the 'nodule,' the 'stripe,' the 'kittle,' the 'green meadow,' and other odd designations.

We will suppose that any of these kinds of ironstone have been mined by gunpowder, brought up to the top of the pits, wheeled along the railway, and deposited near the blast furnaces at either of the two works. The next question is—how to extract the metal from the ore. The other ingredients being almost entirely valueless, the object of the smelter's attention is to get as much iron as possible from the ore; and his plan is, first to drive off those impurities which will escape in the gaseous form, and then to act on the more refractory ingredients.

The process of *roasting* the ore is for the purpose of effecting the first of these two changes, as well as for bringing the ore into a state more readily acted on in the furnace. It is thus that huge heaps accumulate near the furnaces; all the stony masses being slowly burned or roasted in the open air before being thrown into the furnace. In some districts the roasting is effected in furnaces, the new ore being supplied at the top as fast as the roasted ore is extracted at the bottom. The carbonates of iron, however, do not bear a high heat; they melt in the furnace before carbon has any influence upon them, and if there is much admixture of foreign matter, they are apt to produce but a small quantity of iron, with black cinder. The roasting of carbonates—the common ore in this country—is therefore a matter of some nicety; the best means of roasting them are, low heat, and, if possible, access of watery vapours, partly to carry off the heavy carbonic acid gas, and partly to prevent a too high temperature; for, if the heat is too strong, the carbonate melts together with the oxide, and forms, as we have stated, a black cinder. To obviate this danger, they are best roasted in mounds, which are formed on a level ground, and are sometimes surrounded by three stone or brick walls, the area, or hearth, being open on one side, so as to admit the entrance of wheelbarrows or carts; the walls are about three feet high, and have at their bases fire chambers, where the fuel is applied. This is shown at *a*, *a*, *a*, *a*, fig. 2. Through the piled ore are draft holes, or

Fig. 2.



chimneys, *b*, *b*, which regulate the draft; by these chimneys the draft may be altogether stopped when the ore gets too hot. This kind of oven, or mound, which is very useful for small ores, and those which cannot bear much heat, is often used in America. But at most of the larger works in this country, the roasting is effected by simply piling the ore in heaps, with alternate layers of coal, in the open air. First, a layer of coal is spread on a large level piece of ground, then a layer of ironstone in pieces of moderate size, then another layer of coal, and so on to the height of several feet, an external thatching, or coat of small coal, being laid over all. A fire is kindled at one end, and works its way slowly to every part of the mass, roasting the ore as it proceeds. It may be laid down as a rule, that the longer the fire remains in a pile, or the slower the roasting is carried on, the better will be the result.

Mr. Houldsworth has lately taken out a patent for the calcination of the ore and lime by means of the waste gases, which have been generally allowed to flow off unheeded from the mouths of the smelting furnaces. This method has been carried into practical effect at the Coltness Iron-works in Lanarkshire, where the operations with the gas are already applied to three of the six furnaces in blast; and, having been found to work with success, are in course of being applied to the others. No material alteration is made in the original form of the furnace, to adapt it to this improvement. The mechanism for the conduction of the gases is towards the upper part, immediately beneath the openings for introducing the ore, where there is an annular flue constructed in the wall or stonework of the building. The gases are admitted into this flue from the interior of the furnace by circular or rectangular openings; and from the flue they escape by pipes, by which they are conducted to flues or open spaces surrounding the calcining kilns. At the bottom of each of the kilns is a fireplace in which the gas is ignited before entering the flues, and these flues again communicate by openings with the interior of the kilns. An arrangement is also made for admitting air into the kilns to promote the ignition of the gases. The ironstone or ore to be calcined is supplied to the kilns by charging doors at the top of each, a line of rails being laid along and over the kilns for the passage of the charging waggons. When the ore is sufficiently roasted, the gaseous current is cut off from the kilns by a valve; the latter are allowed to cool down, and the ore is removed by doors at the lower part.

The requisite draught is obtained by a chimney which acts for a series of any number of kilns. The ascending gases, flame, and unconsumed vapour, passing up through the body of the kiln, escape through the top of the latter into a long connecting flue built along the range of kilns, and communicating with the chimney.

It seems to have been fully ascertained, after a sufficient trial, that by the application of this process the coal and lime required per ton of iron is not increased, and that ironstone calcined by the gases in close kilns is easier reduced in the furnace, requiring in reality a less quantity of coal. The economy of this mode of calcining *clay-band* ironstone, is said to be at least 2s. 6d. per ton of pig-iron.

The superiority of the celebrated *black-band* ironstone of the west of Scotland consists in the fact, that it contains in its own composition a sufficient amount of carbonaceous matter to roast or calcine it, and that, when calcined, it is free from the clay contained in the argillaceous carbonate. The black-band ironstone, therefore, does not require the above process, and even when accumulated in heaps for roasting, it does not require the interposition of alternate layers of coal. Thus an important economy of fuel is connected with its preparation.

The 'raw-mine,' or 'green-mine' (for the workmen apply the term 'mine' to what we have called ore or ironstone), having been converted into 'burnt-mine,' by one or other of the processes above stated, it is ready for the blast furnace, to have the earthen ingredients removed from it. This is done by a process which illustrates what by chemists is called 'affinity.' Lime and clay have a greater affinity for each other, or a greater tendency to combine together, than either of them with iron; and the smelter takes advantage of this circumstance to separate the metal from its accompanying impurities. If the ore be an argillaceous or clayey ironstone (which is generally the case), he adds limestone to it; if it be a calcareous or lime ironstone (which in some places occurs), he adds clay. Thus, the ironstone of the Forest of Dean, in Gloucestershire, contains lime, and requires clay as a flux or separator; while the ironstone of Derbyshire contains clay, and requires lime as a flux. The mixture of both kinds of ore, however, improves the quality of the iron.

But something more is necessary than ore and lime; there must be fuel to generate a heat sufficient to effect the separation.

This fuel is either coal or coke, and used in former times to be charcoal. The changes from one to the other of these three kinds of fuel, have marked important epochs in the history of the iron manufacture. Before the coal-mines were much used, and when our forests supplied fuel not only for domestic purposes but also for manufactures, iron was smelted with charcoal, as it is indeed at the present day in many foreign countries. Iron smelted with charcoal is, from the purity of the fuel, of very fine quality; but our national manufacture would have been almost utterly extinguished long ago, from the exhaustion of the supply of wood, had not the use of coal been introduced. The employment of coal, however, was not available in its native or raw state, since the sulphur and other foreign ingredients contained in coal would greatly injure the quality of the iron. It became necessary, therefore, to convert the coal into coke; and hence arose the construction of vast coking heaps or 'hearths' at iron-works. At some works the coke is made in ovens, as described in a former paragraph; while in South Wales and Staffordshire it has been the custom to place the coal in the open air, in heaps containing thirty or forty tons each, and allow it to burn in a smothered or confined manner, covering the heap externally with ashes and earth to keep in the heat—a process which adds much to the vivid glare of the district at night.

But the *hot blast* bids fair to lessen, and perhaps to supersede, this wasteful mode of making coke, by affording the means of smelting with coal in its uncoked state. This most important invention cannot well be understood till after noticing the general operations of a blast furnace, to which we will at once therefore proceed.

A blast furnace of the usual construction has internally a square receptacle at the bottom, called the *hearth*, measuring about a yard in each direction. Above this is a cavity of varying shape, extending to the top, and in which the minerals are placed; the hearth being the receptacle for the melted iron as it flows from the ore. The proportion of the ingredients introduced varies according to circumstances; among others, by the introduction of the hot blast. For one of the kinds of

Fig. 3.

iron, two tons thirteen hundredweight of roasted ore, two tons five hundredweight of coal, and one ton of limestone, are put into the furnace for the production of one ton of iron. The materials, as we before observed, are brought to the furnaces by railway from the pits. They are transferred to a most ingeniously-constructed carriage, where there is an iron vessel suspended at one end of a long balance or steelyard, which can be so weighted as to balance with any given quantity of mineral in the vessel. The vessel is a cylinder with a loose conical bottom, apex upwards, and this bottom is capable of being lowered so far as to let the contents of the vessel escape. A given weight of coal is put into the vessel, and a man wheels along the carriage to the mouth of the furnace, which is near the top, and is about six feet square, exhibiting a vast and fiercely-heated body of flame from the mass of burning materials beneath. This upper portion of the furnace, and the method of injecting the ore or fuel, are indicated in fig. 3. The carriage is wheeled on until the vessel passes into the furnace itself, and the man turns a handle whereby the conical bottom is lowered, and the coals precipitated in a circular stream into the furnace; after which the carriage is withdrawn, and a charge of ore and limestone similarly introduced. This mode of charging is a great improvement on the common method, where the materials are thrown in from a handbarrow in such a way as to fall unequally into the furnace, falling to one side rather than to another.

The charges or fillings keep on uninterruptedly three or four times in an hour for day and night, never suffering further stoppage until the furnace is to be 'blown out,' either for repairs or through depression of trade. As the mass within sinks as fast as it melts, so is the supply kept up by addition at the top, so that a furnace of large size usually contains more than a hundred tons of burning materials at all times.

We next come to notice the *blast*, by which the requisite intensity of heat is maintained. So enormous is the mass of burning materials, and so great the heat required for the separation of the iron from the ore, that any of the ordinary modes of supplying air or draught would be inefficient: there must be a constant and powerful current irresistibly forced on by a powerful engine; and this current is called the blast. There are three apertures in the lower part of each furnace, on three sides of the hearth or receptacle, and in these apertures are inserted tubes called *twyeres* or *tweers*, analogous to the nose of a bellows. These twyeres are connected with a large reservoir or regulator filled with compressed air, the compressed air so stored being forced into the regulator by a powerful steam-engine, acting on the principle of a forcing-pump. If the air were forced by the engine at once into the furnace, it would produce an intermitting, irregular blast, almost powerless at one instant, and excessively strong in the next—an alteration which would greatly injure the operation of the furnace. A regulator is therefore provided (analogous to the fly-wheel of a machine), by which an equable supply of air is forced into the furnace. The blast regulator is, at one of the works, an enormous cylinder of iron, thirty feet in height by nine in diameter, and therefore capable of containing nearly two thousand cubical feet of air. The success of the smelting process greatly depends on the manner in which this blast reaches the mass of burning materials, and there are various minor adjustments whereby this can be regulated. Occasionally, the hinder end of each twyere has a hole covered with a piece of talc, through which the fire can be seen; and from the whiteness of the heat the smelter judges how the process is going on.

Now, it is the substitution of *hot air* for *cold air* in the above operations that constitutes the hot-blast system. The cold blast has a tendency to chill the mass of melted materials on which it is projected, and it was long suspected that great waste of fuel resulted thereby. It remained for Mr. Neilson, however, of the Clyde Iron-Works, to introduce an efficient remedy. About twenty-five years ago he took out a patent for warming the air before it was introduced into the furnace, conceiving that the quantity of fuel so expended would be amply compensated by the efficiency of that employed in the furnace itself. The invention made its way through many difficulties, and it gradually came into use throughout the iron-works of Scotland, and in many of those in England and Wales, under license from the holders of the patent. The patent expired ten or eleven years ago; and the use of this method is rapidly extending, not only in this country, but on the Continent. At first the air was heated to about 300°, but as there seemed no reason why it should not produce better effects if heated yet higher, the temperature was gradually increased to 600°, or equal to the temperature of melting lead. The principle is simply as follows:—Near the furnace is a stove-room, so arranged as to heat a series of iron pipes to any required degree of temperature. The pipes may be of any shape thought most desirable; and

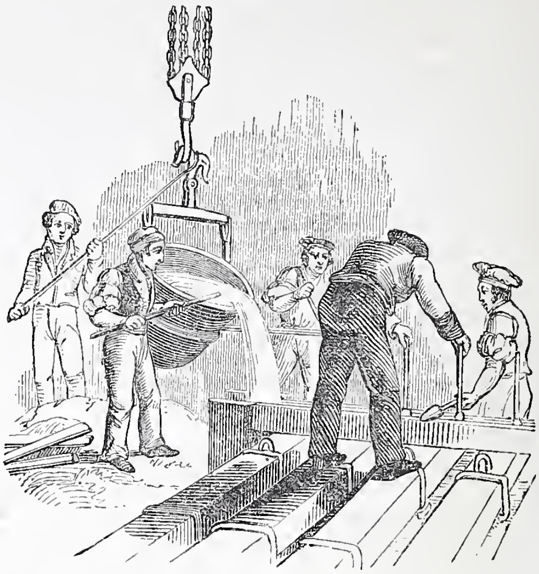
the air passes through them on its way to the furnace, deriving heat (usually about 600° Fahr.) as it passes. One of the good effects of this system is, that it is found coal may be used in smelting instead of coke, whereby a great saving is effected; and therefore at those works where coke used to be employed, coal is now used in the raw state, just as brought from the mine.

The liquid iron resulting from the action of the furnace is allowed to accumulate for twelve hours, at which time it is *tapped*, or allowed to flow out. There is a small hole at the bottom of the furnace, which is filled with clay after each tapping, and is broken open when the next tapping is necessary. In addition to this there is an opening somewhat higher, at which the scoriæ, or floating impurities, flow off from the surface of the metal; the colour, consistence, and general appearance of this *slag* denote to the smelter the mode in which the process is going on. The slag flows into cast-iron boxes, and is thence removed to be used for roads, rough walls, and other coarse purposes. The iron is generally cast into rough oblong pieces, called *pigs*, in the following manner:—In front of the furnace is a flat earthen space, covered with sand, and in the sand are made depressions or channels by a pattern, the counterpart of the pig. Down the middle of this space is one long channel, called the *sow*, from which branch off a hundred or more lateral channels or *pigs*, which, in the odd language of the workmen, "suck the metal from the sow." All being ready, the clay stopper to the hole in the furnace is broken away, and the white-hot liquid metal pours forth in a stream, and is conducted by a trough to the sow, from whence it branches laterally into the pig moulds. One by one these moulds become filled with the glistening liquid, until at length the whole present a most vivid and remarkable appearance. The masses or pigs soon solidify, and are removed from the moulds while in a hot state; and the hole, or tap, is securely closed up preparatory to another similar train of processes.

Sometimes the metal, instead of flowing into pig moulds, flows into a larger mould for forming some ponderous piece of cast-iron; but more frequently it is, for the latter purpose, received in ladles or large vessels, and from thence poured into moulds. We may illustrate the various modes thus:—A part of the supply of melted metal is received in pig moulds, while the remainder flows into a large iron vessel sunk in a hole in the sand. When filled, this vessel is raised by a powerful crane, swung round to another part of the foundry, where moulds for pipes have been prepared, tilted up, and the melted metal allowed to flow into the pipe moulds. In some cases, a vessel of white-hot liquid iron, weighing from one to five tons, is transferred from one crane to another, and thus conveyed to the end of the foundry, at a considerable distance from the furnace. In other cases, where more convenient, the pigs of iron are remelted in smaller furnaces, called cupola furnaces, and thence poured into moulds.

The mode of casting metal pipes, just alluded to, will illustrate many different varieties of iron-founding. There is formed, in the first place, a core or central pattern of cast-iron, with alternate grooves and ridges extending from end to end. Round this is wrapped a covering of hay or straw rope, and this rope is plastered with a layer of wet loam or clay, worked until the exterior surface becomes cylindrical, and corresponding in diameter with the internal dimensions of the pipe to be made. From this mode of formation, it follows that there are hollow channels or gutters beneath the straw-rope, and these serve for the exit of heated air in the subsequent processes. The core, when formed, is sprinkled with powdered charcoal, and placed in a heated oven to harden. Meanwhile, the mould for giving the external form of the pipe is being prepared. A model, or pattern, is made, corresponding exactly with the exterior of the pipe to be cast, and with this pattern a mould, or cavity, is formed in a smooth bed of sand, in two halves. Then, when the core is placed and supported concentrically in this mould, there is a cylindrical space between the two, equal to the thickness of the intended pipe. Holes for the admission of the melted metal, and others for the exit of the heated air, are provided, and the metal is poured in from the ladles or vessels before alluded to, as shown in fig. 4. It will be plain, on a little consideration, that the exterior of the core must give the interior form to the pipe, while the interior of the mould must give the exterior form to the pipe.

Fig. 4.



In casting pipes of large diameter, the core and mould are built up vertically in a pit as deep as the pipes are long; and matters are so arranged that the liquid metal is poured in at one end. In casting large cylinders for steam-engines and other purposes, the formation of the mould and core is a matter of much importance, each being formed of brickwork built up cylindrically, and of such dimensions that the larger may enclose the former, leaving a space between them equal to the intended thickness of the metal cylinder. The outer surface of the inner cylinder, or core, and the inner surface of the outer cylinder, or mould, are wrought very smooth and regular; and both cylinders being adjusted in a pit, melted metal is poured into the vacuity between them. Thus is the cylinder formed. The process of *boring*, to which such cylinders, as well as cannon and other articles requiring a smooth interior, are afterwards subjected, is not, as the name seems to imply, the boring or making a hole, but a planing, scraping, or cutting away of the inner surface, till it becomes regular and smooth from end to end.

In all large specimens of casting, such as bed-plates for marine engines, arches for bridges, beams for roofs, plates for large cisterns and tanks, turntables for railways, framework for engines and machines of various kinds, and such like, the mould is made in sand on the floor of the casting-house, from moulds or patterns previously constructed in accordance with the working drawings, and the liquid metal is poured into these moulds at once from the blast furnace, or from the ponderous vessels, or from a cupola furnace, according to the circumstances of the case.

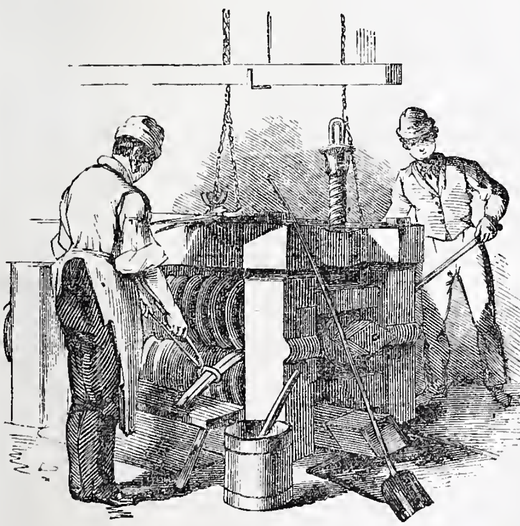
Thus far the operations belonging to what is termed iron *founding* or casting, and they constitute a series full of interest, both to the intelligent inquirer as well as to the mere spectator. But the production of *wrought*-iron, involving the operations of the *forge* and the *mill*, constitutes a distinct series, at which we must next take a rapid glance.

All wrought-iron is made from "pigs," and is therefore equally dependent with cast-iron on the operations of the blast furnace. The pig-iron is of various qualities, according to the purposes to which it is to be applied; and we will suppose it to be such as is fitted to make railway bars, or sheet-iron, or any other kind of wrought-iron. The masses undergo the process of *refining*, as preparatory to the other operations of the forge. The carbon and the oxygen contained in the pigs of iron appear to be necessary to the process of founding, but to interfere with the production of malleable iron; and the process of refining,

as well as the next one, of *puddling*, seems intended to drive off the greater part of these ingredients. The furnace employed for refining the iron is generally a low structure, having a hearth, or bottom, of fire-bricks, and the sides of cast-iron, made hollow to allow a stream of water to pass constantly through, as a means of preventing them from being burnt away by the intense heat within. There are doors at the sides for the introduction of the metal and fuel, and a brick chimney over. The pigs of iron are placed on the hearth of a low cast-iron furnace, and covered with coke and slag; they are then exposed to an intense heat, excited by blast-pipes, until the metal becomes thoroughly melted. An aperture in the lower part of the hearth is then opened, and the white liquid metal flows into a flat mould of cast-iron, where it is almost instantly chilled by means of cold water. These long slabs of refined iron are next broken in pieces, and put into the *puddling furnace*, where the brittle texture is exchanged for one much more malleable and ductile. The puddling furnace is one in which the flame and heat are reverberated from an arched roof, and made to strike down on the metal. The broken fragments of refined iron are placed upon a hearth or floor, and a fire kindled by the side in such a situation that the flame passes over an intervening bridge, and is then reflected down upon the metal. This mode of applying heat has the effect of driving off the remaining carbon and slag. As soon as the iron begins to melt, the "puddler" watches the progress of the operation through a hole in the front of the furnace, and by means of a long bar stirs the pieces of iron, till all are equally acted on by the heat. When once the whole is melted, the puddler keeps the mass constantly stirred, changing his bars every few minutes to prevent them from melting. This operation, which exposes the workman to a great heat, is continued until the iron, by giving off an elastic fluid, becomes thickened, and separates into pasty lumps. These lumps are so turned over and combined by the puddler, by means of his rods, or bars, that he forms the whole contents of the furnace into five or six masses, called *balls* or *blooms*, averaging probably sixty or seventy pounds weight each.

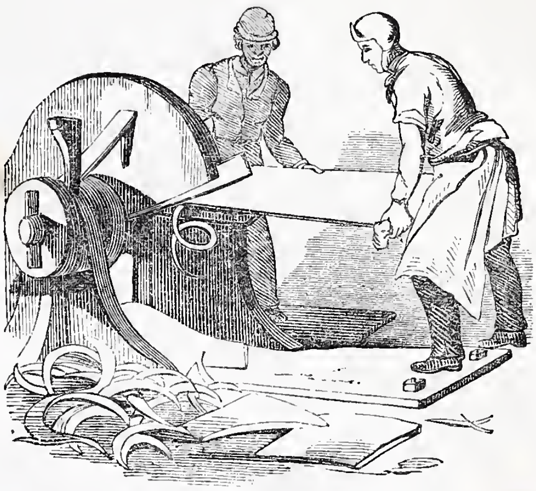
Then ensues a series of operations, in which the fiery ball of iron passes from one workman to another with great rapidity, and gives a vivid and very bustling appearance to the forge-house. One of the blooms or masses is taken out of the puddling

Fig. 5.



furnace by means of a kind of tongs, and is quickly passed to the *shingling-hammer*. This ponderous machine, which sometimes weighs five tons, and requires a steam-engine of twenty horse power to work it, is simply a hammer worked up and down several times in a minute. The bloom is placed under this hammer, and is speedily wrought into shape, the workman turning it round so that it shall receive blows on all its sides, until at length it is hammered into a square or rather oblong piece. Then, before this piece has time to cool, it is passed to the *puddle-rolls*, which consist of a pair of very large, hard, and heavy rollers working against each other, and having grooves on their surfaces. A man takes up the mass of iron, and places one end between the rollers; it is instantly seized by them while revolving, and passed between them, receiving at the same time an elongated form from the groove through which it passes. Another man behind seizes it with tongs as soon as it is protruded (see fig. 5), and transfers it back to the first man, who passes it through a smaller groove, and so on until the iron presents the form of a rough flattish bar, two or three yards in length.

Fig. 6.



The iron is not yet in a finished or saleable state; it still retains some of its former brittleness, and has another heating process to undergo. The rough bars are cut into pieces, piled together in groups of five or six each, and placed in the *balling furnace* (a name which will probably appear to be a very inappropriate one), shaped a good deal like the puddling furnace. Here the bars are heated to a welding heat, and when taken out they are passed through rollers acting in the same way as the puddle-rolls, but having grooves of a flat, square, triangular, or circular form, according to the shape to be given to the bars; or it may be that the grooves are such as will produce railway bars. By this mode of welding five or six bars together, the iron acquires a toughness and malleability which it did not before possess; and in the case of iron of very superior quality, the same process is conducted a second time. In every pair of rolls the grooves diminish in size from end to end, so that, as in the process of wire-drawing, the rod of iron becomes smaller and smaller at every successive drawing between the rolls. The two men, each with his tongs, manage the gradually elongating and still heated piece of iron, passing it to and fro, the one inserting it between the rolls, and the other seizing it as it protrudes, and passing it back to his fellow-workman. Sheets of iron are made precisely in the same way, the rolls being of such a size, and having such flatness of surface, as will lead to the production of a broad thin sheet, instead of a bar or rod.

The bars and sheets of iron thus produced have little more to undergo before they leave the works. To reduce the bars to proper lengths, and the sheets to proper lengths and widths, they are subjected to the action of powerful shears, which cut the iron with a facility well calculated to astonish those who witness the process for the first time. The cutting of boiler-plates by this process is shown in fig. 6. The lower blade of each pair of shears is fixed, while the upper blade is moved slowly up and down by the power of a steam-engine; and the bar or sheet to be cut is held by hand on the lower blade, so that the upper one may act upon it. In the case of railway bars, which must fit very accurately end to end, and which must be very exact in length, this mode of cutting would not be precise

enough. The bars are in this case placed on a bench, to which a guage is attached, and the iron is cut by means of circular saws about a yard in diameter.

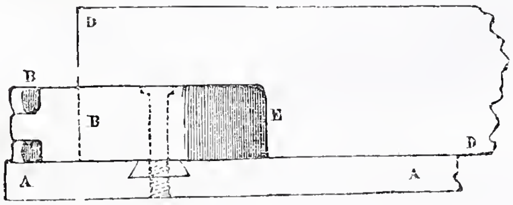
The business of the iron-maker here ceases. He has made bars and sheets of iron; and these now pass into the hands of others, who fashion from them the countless articles of every-day life, from a nail to a steam-engine. At such establishments as those which we have in view, the diversity of things and of processes gives an appearance of incessant bustle and activity. The quarries whence the limestone is wrought, the mines which yield the ironstone and the coal, the canals and railways which transfer these minerals from one place to another, the ovens where the coal is coked, the ridges where the ironstone is roasted, the furnaces where the ore is smelted, the casting into 'pigs,' the founding into large pieces for engineering, the refining, puddling, shingling, and rolling, whereby cast-iron is changed into wrought—all form a scene of excitement not soon forgotten when seen.

DE JAY'S CARPENTER'S SELF-ACTING VICE.

The object of this contrivance is to give stability to a board during the operation of planing its edges; the simple act of thrusting the board into the jaws of the machine fixing it fast without further adjustment.

The vice is mounted on a planing-board, A A (figs. 1 and 2), which is to be placed on the bench and stopped by the bench-hook. It consists of a pair of jaws, B B, made of beech or other hard wood, turning on upright iron pivots or screws, C C. When the board, D D,

Fig. 1.



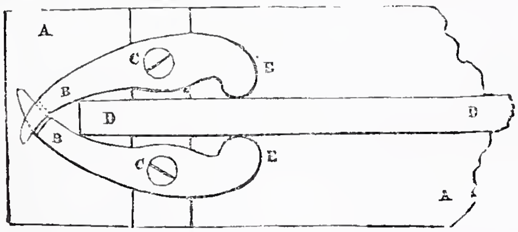
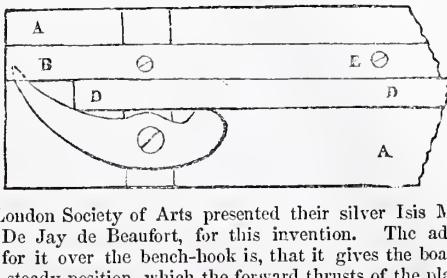


Fig. 2.

of which the edge is to be planed, is driven into the jaws, it acts as a wedge, and the force tending to separate them is transmitted backwards by leverage to the tails, E E, which are pressed against the sides of the board, and hold it firmly locked.

At the angular junction of the ends, B B, they are partly crossed, a tooth on the one fitting into an opening in the other. By this arrangement, these ends are not completely separated, even when the tails, E E, are placed in contact; and thus, if the board be ever so thin, it will find an abutment.

Fig. 3.



The London Society of Arts presented their silver Isis Medal to Mr. H. De Jay de Beaufort, for this invention. The advantage claimed for it over the bench-hook is, that it gives the board to be planed a steady position, which the forward thrusts of the plane tend to increase. The advantage over the vice is its self-action, "and the superiority of the workmanship, the board being supported in all its length, instead of at one point only, at each end." The inventor names it a Jay, "being desirous that his name should be for the working class synonymous with diminution of labour."

A modification of this plan has been proposed, in which there is only one acting jaw, and for the other is substituted a rest B E (fig. 3), running the entire length of the planing-board, A A, and firmly fixed to it. This does not detract from the simplicity of the vice, and increases the stability of the board, D D, during the operation of planing its edges. The fixed jaw, besides, makes no impression on the side of the board bearing against it.

Figs. 4 and 5 are sketches of a similar contrivance, by Mr. R

Fig. 4.—A plan of the vice.

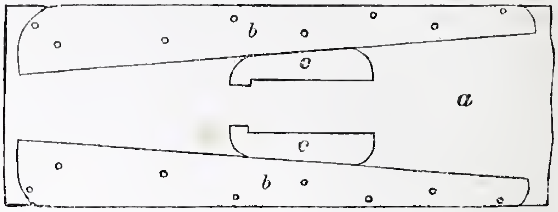
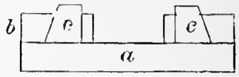


Fig. 5.—An end view.



Bowery, of London, which obviates the difficulty often experienced in holding short pieces of wood for planing smooth and true, without the aid of the bench-vice. In this simple apparatus, also, the work merely requires to be inserted, and gently pressed up to the small end to fix it firmly, without indent or impression of the vice, as in the above contrivance of De Jay, with its jaws and joints.

a (figs. 4 and 5) is a board of any convenient length, to lay on the bench; *b b*, two pieces of hard wood, firmly screwed to the board, with the inner edges bevelled; *c c*, two wedges of hard wood, bevelled also, to fit the side-pieces, with a gib or small projection, to form the stop for the board which is to be worked upon.

FENN'S PATENT COACH WRENCH.

The annexed figure is a sketch of Fenn's patent coach wrench, which has, perhaps, a better claim to the attention of practical engineers than most varieties of this tool which have preceded it. In a great majority of these the screw is used to adjust the opening between the cams of the wrench, but in that introduced by Mr. Fenn (Toolmaker, Newgate Street), the moving cam is mortised out so as to slide with perfect freedom on a square bar of iron or steel, and it is securely fixed to this after being set to any required opening by a lever and wedge—the lever forming a portion of the handle of the tool, as will be readily understood by the figure.

The principal advantages of the tool are its non-liability to get out of order—the great facility it affords for being set to any required guage, without the trouble of turning a screw, and its power of withstanding any force that can reasonably be applied to it, without in the slightest altering the distance between the cams. This property has been tested very severely, and found to be quite perfect. It is true that the same thing may be said of some of the best screw-wrenches, *when new;* but then, as there always must be some amount of shake between the different parts, this will, of course, be constantly increasing, and soon render the instrument less efficient. Mr. Fenn's instrument is entirely free from this defect; for the fixing wedge draws the cam so completely in contact with the bar on which it slides, as to render any shake impossible, and, from this circumstance, we may fairly conclude, that it will be as durable as it is effective.

HISTORY.

CHAPTER XVIII.

THE GERMANIC TRIBES—CHARLEMAGNE.

A New people is about to appear upon the stage of history: the Germanic Tribes, established in the ci-devant Roman provinces. The information we possess regarding these tribes, prior to the erection by different divisions of them of new States upon the soil of the Roman empire, is neither very full, very distinct, nor very consistent of itself. From the traditions of the tribes themselves which have survived we derive no additional information. They seem to have been rubbed out of their memories, or disfigured by the stirring events of the overthrow of the Roman empire, and the frustrated attempt to erect a new western empire. What little can be predicated of these tribes previous to their invasion of the Roman territories is nearly as follows :—

These tribes in the time of Cæsar inhabited that extensive country north of the Danube and east of the Rhine. The limits of the territories occupied by them to the north and east are unknown ; for it is only through the writers of the Roman empire that we know any thing of them : and it was only along the Rhine and Danube that the Romans came in contact with them. Their physical characteristics were fair ruddy complexions, light reddish or auburn hair, and blue eyes. Their language, or languages, were kindred dialects of these (spoken or dead) which we still retain in the Maeso-Gothic, Anglo-Saxon, Norse, Allemannic, and other derivatives of the middle ages or the present day. They vary among themselves more than the Greek dialects, but less than the Semitic languages ; in all of them the logical and physical laws are substantially the same ; in all of them the radical vocables are the same in form and meaning. This similarity of physical constitution and language satisfactorily points to one common origin. The language is one of those belonging to the great family to which the Sanscrit, the Zind, and Pehlui, (ancient dialects of Persia,) and the Greek belong. It will be remembered that the auburn or yellow hair is as marked a characteristic of many Greek heroes in Homer, as it is of Germans in Tacitus.

So late indeed as the time of Tacitus, the tradition of a common origin was retained among the Germanic tribes, which he has preserved on record. From the analogy of the Italian states, of the history of which we find traces in the early annals of Rome, and from the dim indications we have in Grecian writings of the early condition of the Ethiopic tribes who drunk of the lower Nile, and of the Persian and Median clans, it seems almost allowable to infer that whether Tacitus be correct in his names or not, he has here preserved us an authentic record, the meaning of which is : that the Teutones (or descendants of Teut), were originally divided into tribes named after his sons (as in the case of the Hebrews) ; and that as one of these came in the lapse of time to split into several clans, and several clans to form themselves into a confederation with a common name, each new Germanic state sought to ingraft itself on the original family-tree by attributing to their fabulous ancestor Mannus another son, to whom they gave the name which themselves had assumed.

The glimpses of the constitution of society among these tribes, which we gather from the Roman writers, corroborate this inference. We find the traces of an old and simple constitution, in which every freeman—that is, every male of pure descent, and past his one-and-twentieth year, is entitled to a voice in the public transactions of the settlement or community of which he was a member. We find in different parts of Germany confederacies of several settlements, in which, while the old constitution was preserved for the regulation of local affairs, the public business of the union was managed by the leading men of each community ; how they were appointed does not clearly appear. We find also that these unions, not satisfied with defence, forcibly incorporated into them many neighbouring communities and confederacies of Germanic origin, and made war upon the Gauls and other northern races. Hence a class of warriors sprung up—I do not mean the freemen, all of whom were warriors—but men who made war their trade, and who, when their own tribe were at peace, would take service with any other people engaged in war.

The accounts we have of the Germanic Mythology are very imperfect. One thing is, however, certain, that, in the words of Tacitus, "they neither dreamt of confining the gods within walls, nor of likening them to any human form ;" that "they consecrated glades and groves, and called by the names of gods, *that sacred something which veneration alone discerns.*" "A glade consecrated to the primitive religion is shewn among the Naharuali (a clan of the confederacy of the Tygiia, eastward of the Suevi, and separated from them by a mountain ridge) ; a priest presides in female apparel, they venerate twin gods without image or name." The Angli and Miors, their associates, worshipped Herthum—that is, "mother earth." Their sacred place was in an island in the sea, where ceremonies were performed at stated intervals, but no image kept. Reverence was paid by all to Teut, the son of Herthum, their common parent. In all his sacred glades and groves unbound steeds of pure white were maintained at the public expense, and auguries drawn from their neighing. Another mode of augury was by lot. A twig from a tree was cut into pieces of varying size and form ; an arbitrary meaning was secretly attached by their soothsayers to each ; these casts were scattered on a garment, and one or more picked up with closed eyes. Another mode of augury was used previous to engaging in a war. A captive of the enemy was detained by surreptitious means. He was armed, and set to fight a duel with one of their own chosen warriors. The result of the combat was deemed prophetic. Lastly, they pretended to divine by the voice of birds and beasts. These are the salient points of German society during the period which elapsed between the foundation and the overthrow of the western empire.

The majority of the German clans and confederacies were cultivators of the soil. Their long leisure hours were occupied with eating, drinking, and listening to old songs. The chase also was at once an amusement and a school for the warrior. Along the Rhine and the Danube they became acquainted with the use of money. The subjected tribes of Gaul worked for them the iron mines of Rhaetium, and thus their poverty in iron weapons, noticed by Tacitus, gradually diminished. The Germanic tribes, north of the Danube and east of the Rhine, maintained their independence despite the most strenuous efforts of the empire. It was found expedient by the latter emperors to take into pay the most influential *fursten* (or firsts) of the various followers among the confederacies, next neighbours to the empire as guards against encroachments from the tribes which lay behind. By this means the wealth and power of these princes was augmented, and in many of the confederacies a rude limited monarchy began to supersede the old republican institutions. Quarrels between these princes and Rome generally ended in some of their families or noblest followers being sent as hostages to the capital, where they not unfrequently picked up a smattering of Roman policy and tactics. On their return to Germany, ambition and a conscious superiority to their countrymen led them to form bolder schemes of dominion, and thus more remote tribes and new combinations of tribes were introduced to the knowledge of the Romans. It will be remembered that at no time was the pure Roman race more than a small fraction of the population of the empire. Incessant wars during the continuance of the republic, and misgovernment during the empire, had materially thinned the population of the provinces, and even of Italy itself. Large bodies of German mercenaries, permanently stationed in garrisons with their wives and families, became in time no unimportant ingredient in the population of the empire. A constant communication was kept up between these Germans domiciled within the empire and their kinsmen beyond the Rhine and Danube. Raw recruits joined the soldiery ; and often a longing for his early home led an old soldier to obtain his dismissal and return to Germany. By this means the Germanic body advanced rapidly towards an equality of warlike skill with the Romans, whom they far surpassed in robustness. They learned to look down upon the citizens of the empire as all hardy and uneducated or half-educated classes—sailers and the like—do upon mere civilians. Their leaders in the meantime were, from motives of policy, caressed by the court ; and as the emperors could place more reliance upon their blunt honesty than upon that of the corrupted courtiers by birth and breeding, we not unfrequently see them filling important stations in the empire towards its close. Thus was the southward motion of the Germanic tribes insensibly prepared ; and when it took place it occasioned rather changes of dynasties than any of a more decided character.

The first visible step of this great movement took place in the year 394. On the death of Theodosius the Great, the empire was divided : the eastern half being assigned to Arcadius, and the western to Honorius. This event was pregnant with important consequences, brought about by the enmity that existed between the ministers of the two monarchs. The Goths had sought refuge from the Huns, an oriental race, in the territories of Arcadius and Honorius ; Stilico, the minister of Honorius, claimed the wardship of both emperors, and intrigued with the Goths resident in his territories, and with their persecutors, the Huns. After a series of hostilities, managed with various degrees of success, he became involved in a

course of intrigue directed against himself, which terminated in his execution at Ravenna early in the year 408. The intrigues which followed upon this event, issued in the establishment of three new dynasties in as many Roman provinces :—the Vandals in Africa ; the Goths in Spain and Aquitaine ; the Burgundians in the upper Rhine and upper Rhone. Britain, the fourth in number, fell to the lot of a mixed tribe of Saxons, Yules,and Angles. The Picts and Scots had ravaged the Roman portion of Britain several times before the year 400. The withdrawal of the garrisons from the island between 400 and 404 by Stilico, and still more the subsequent withdrawal of the flower of the troops by Constantine, left the Britons of the Province more than ever exposed to the incursions of their wild neighbours. In 440, two brothers of Saxon race, Hengist and Horsa, landed, upon the invitation of a British prince, in south Britain, in the character of his allies. They soon turned their arms against him, and kindred hordes, following their example, obtained settlements all along the west coast of Britain. In the year 579, the island of Great Britain, from the line of the wall connecting the Forth and Clyde to the Land's End, was settled by Germanic tribes, with the exception of Cornwall, Wales, and the Galloways.

And next came the turn of Rome and Italy to own the Germanic yoke. But first a temporary inroad from a power alike hostile to Rome and the Germans was destined to assail Italy, Burgundy, and the Visigoths, in the light of equal, independent, and allied powers.

Attila, the greatest of the monarchs who reigned over the Huns, after a murderous battle with the Romans under Aetius their general, died in the year 450. His death loosened the only tie which held his subject tribes together, and ere many years had elapsed the very name of the Hunnish power had ceased.

Rome had been more than once subjected to external invasion. But the first revolution that was to establish a German on the Roman throne came from within. In 476, Romanus Augustulus—called by a diminutive appellation, as if in derisive prophecy—was dethroned by his German guards, and all the troops of that race in Italy adhering to their countrymen, their commander Adeacer was declared king. Adeacer speedily reduced Rome and the whole of Italy to submission, and obtained the cession of Sicily from Genserich by pacific convention. He did not assume the imperial title, nor did he call himself king of Italy; he called himself king of the Heruli, Rugii and Turcituuji, (Germanic tribes of the oldest and noblest) in Italy. He formed alliances with the Visigothic and Vandal kings. He was destined however, to be the only king of his dynasty. Theodoric, king of the Astregoths, with the sanction of the Byzantine Court (in which he had lived ten years as a hostage), crossed the Alps in 489, and in three successive battles drove Adeacer from the field. The king of the Heruli took refuge in Ravenna, but was starved into surrender, and not long after put to death by Theodoric. The kingdom of the Astregoths thus founded embraced Italy, Sicily, part of Provence, the country north of the Alps to the Danube, and part of Dalmatia. Although Theodoric, more fortunate in this than Adeacer, transmitted his crown to his successors, his dynasty was not of long duration. The state of the Astregoths was subdued by the generals of Justinian in 554. The southern regions of Italy continued for some time in the hands of the Byzantines; but a new Germanic kingdom immediately sprung up in the north—that of the Lombards, which was founded by Albein in 568, and lasted till 774.

The Franks first appear in history as a confederacy of independent states on the banks of the Rhine. In 407, they were borne down by the successive attacks of the Vandals and the Burgundians, but were enabled to retain their places by the assistance of their allies the Saxons. From that time till the year 508, they bore the character of invaders, and under their leader Chledwig, made various successful inroads on the territories of their neighbours. In 508, Chledwig was appointed a patrician of Rome, by the emperor Anastasius—a title which implied his powers of governor, and was accompanied by a dress more tasteful and splendid than had ever before been worn by a Frank leader. Fourteen years before, he had allowed himself to be baptized ; and the undergoing of this ceremony—for his subsequent life will not allow us to look upon it as any better—materially forwarded his ambitious views. The inhabitants of Gaul had as a body been general converts to the Christian faith previous to the inroads of the Germanic tribes. The Visigoths, who made themselves masters of the richest and largest portion of France and all Spain, were also baptized, and confessed the Arian faith. The clergy of Gaul belonged to the orthodox section of the church ; and Chledwig, being baptized by them, received from that moment their zealous assistance against the heretic sovereigns. Sectarian favour and honours from the court of Byzautium — honours which made the former subjects of the Roman empire recognise a bond of citizenship between them and the Frank leader, and which implied scarcely even a nominal dependence—facilitated not only the extension of his conquests, but the consolidation of his power. Up to 508, Chledwig had been contented to remain the most powerful and influential among the chiefs or kings of the Frankish tribes ; but he now aspired to be sole king, and soon determined his end by treachery. In this extent of power and glory he died in the year 511.

The kingdom founded by Chledwig remained in his family for two hundred years. That family, however, degenerated into a state of extreme imbecility, and was succeeded by Charles Martel, who, after successfully resisting the conspiracies of the Frankish nobles, continued to rule without assuming the kingly title. Towards the close of his career, the bishop of Rome, finding himself rudely pressed by the king of the Lombards, and utterly unsupported by the Emperor of Constantinople, sent (this was in the year 741) a solemn embassy to the ruler of the Franks, which brought him the keys of St. Peter's grave, and offered the Roman Patriciate, or the office of defender of the Romish chair, with the assurance that the Romans would acknowledge him instead of the Greek emperor, for their master. For this flattering offer Charles was indebted partly to the habit among the orthodox clergy, of regarding the Frankish ruler as the natural rival of the heretic Goths ; partly to his own victories over the Saracens in Aquitaine, which had put an effectual stop to the progress of Islamism in a westerly direction. The bargain was under the serious consideration both of the Roman and Frankish courts, when both Charles and the bishop of Rome, who made the offer, died. The transaction was, however, resumed at a later period. At his death, the management of the Frankish state was divided among his sons ; but in less than three years, his son Pipin had engrossed the whole to himself. By consolidating the conquests of his predecessors, and making new, he added to the territory of Chledwig, Bavaria on the south-east, Saxony on the north-east, Aquitaine on the south. Having accomplished so much he set himself to convert his title of Major-domus into that of King. Boniface was at that time bishop of Rome, and the archbishop of Mayence was his legate, with all his Teutonic churches. Having won this prelate, Pipin found his superior easy to manage. The activity of Pipin and his father in extending and organising the church in Germany was dwelt upon, and also the importance of enlisting so brave and powerful a leader as the Church's soldier, with a view to any contingent inroad of the Arabs from Spain. With the Pope, Pipin gained the whole body of the clergy, and with the clergy the whole nation. These securities obtained, Pipin sent two priests to Rome to ask publicly which better deserved the Frankish throne, Childerich, the heir of descent, or Pipin the heir of his own and his father's actions. The answer of the Pope, who was well aware that an unfavourable answer would not divert Pipin from his purpose, and who saw preparations making among the Lombards to attack him, was all that the Frankish ruler could desire. Pipin was without delay elected king in the general assembly of the Franks, and avouched by the archbishop of Mayence. Pope Zachary visited him soon after his coronation, and represented to him in strong terms the oppression he suffered at the hands of the king of the Lombards. Moved by those entreaties, Pipin marched against the Lombards, forced them to a restitution of all that they had taken from the city of Rome and the Pope ; and besides restoring to the latter what had previously been the domains of his church, he formally transferred to him the Exarchate of Ravenna. The emperor of Constantinople reclaimed against this gift, but in vain. The Greek influence had never entirely sunk in Italy ; and this first beginning of territorial sovereignty in the Bishop of Rome was clung to by all the successors in the chair, with a tenacity that defied the efforts of the prelates of Ravenna, of the Venetians, and even of Charlemagne to wrest it from them.

Pipin was succeeded in 767 by his son Charlemagne, or Charles the Great. Several of this prince's brothers were originally joined in office with him, but following the example of his father, he contrived to rid himself of them all. He reigned 47 years. In the very beginning of his reign he was invoked by the Pope to fulfil his duty as hereditary Patrician of Rome, by reducing his Lombards to peace. At the close of the campaign, which Charles undertook upon this summons, he was formally installed Roman Patrician, and saluted as king by all the Lombards. He confirmed by charter to the Pope his territory, granted to that prelate's predecessor, by his father Pipin. He subdued all Gaul as far as the Pyrenees. After repeated insurrections, he finally subdued the Saxons and independent Franks, and added to his dominions

all Germany west of the Elbe. Before the death of PopeAdrian in 795, Leo III sent to Charles, as Patrician, the keys of St. Peter's grave, and the banner of the city of Rome, and invited him to send one of his grandees to Rome, to receive in his name the oath of fealty from the citizens. This was a step beyond what was conceded to Charles Martel; it was installing the Patrician in the dignity of the Emperor. About the year 799, a feud broke out between the Pope and the relations of his predecessor, which ended in a public assault and maltreatment of Leo, and his confinement in a cloister. The citizens took part against the Pope. He, however, made his escape, and laid his complaints at the feet of the Frankish monarch. A still higher object of ambition seemed now to dawn upon Charles. He crossed the Alps—instituted a solemn inquisition into the *fracas*—reinstated Leo upon his solemnly clearing himself of all the accusations made against him by a public oath; and at the same time, for the purpose of ingratiating himself with the Romans, punished the adversaries of the Pope as leniently as he could. This business was transacted in November, but Charles prolonged his stay at Rome till the spring. On Christmas-day, he attended the sacred service, and as he was rising at the close, the Pope placed a costly crown on his head; the people saluted him by acclamation with the title of Roman emperor, and the Pope was the first who performed the old ceremony of adoration. Charles was in reality master of the whole territory of the western empire, with the exception of the British isles, and Spain and Africa, which were in the possession of the Arabs. The territories he possessed in Germany, however, which had never owned the Roman sway, seemed to compensate for this exception. A war against the Saracens was a holy war, and his recognition as Roman emperor gave him an especial title to undertake it; and then the throne of Byzantium was at that time occupied by a woman in circumstances which seemed to open up a still wider field for his ambition. After an interregnum of more than three hundred years, the western empire was re-established. The Bishop of Rome and the monarch of the Franks, each individually too weak for the task, accomplished it between them. The former lent his spiritual influence, and the latter the physical force of his sword. The bishop anointed Charles, and Charles secured by charter temporal power and lordships to the bishop, and confirmed him the head of the western churches. Two faulty and defective titles were cobbled together to make out a good one. The object proposed was the mastery of the world. The King of the Franks and the Bishop of Rome proposed to hold it, as the Scotch lawyers say, *pro indiviso*. The one was to reign over men's souls, the other over men's bodies, and each was to make his peculiar power of avail to corroborate that of the other. The arm of flesh soon gave way. The empire did not remain above a hundred years in the possession of the descendants of Charles. But the arm of the spirit prospered, and seemed for a while even to grow stronger by being severed from its mate, nor is its power yet entirely in abeyance.

I pointed out, under the Roman empire, how the constituent and controlling power was lodged in the army. In the changes of dynasty which have been reviewed in this chapter, there was nothing more than a continued snatching of the sceptre from one band of soldiers by another and a bolder and braver band. The investigations of the general principles to be evolved from these narratives, must be reserved for another chapter, as it was impossible to avoid the tedious bead-roll of dynasties with which we have just been engaged.

ON HORSE POWER.

ARTICLE I.

The expression "horse power," similarly to many other technical terms employed and sanctioned by usage in Practical Mechanics, owes its origin obviously to the nature of the primitive sources of power applied to work. The strength of animals, especially the horse, as it was the principal source of available power previously to the discovery and application of the force of steam, became typical of all other species of power, and hence the power of a horse was adopted as the common measure of every other power: it became the universal standard of comparison by which the relative, as well as the positive, values of the powers might be expressed.

Definition of Horse Power.—Horse Power, as a general mechanical term, is synonymous with what Whewell has called *Labouring Force*. The work to be done may be performed by various mechanical agents—by men, by horses, by water, by steam, or by wind. In all these cases, labouring force is generated and applied; motion is produced by the continued exertion of pressure. Labouring force is, then, something more than mere pressure; it is something useful, something which produces an effect that can be measured.* It is, in short, pressure in motion, whereas mere pressure, unaccompanied by motion, does not generate any tangible mechanical effect, as, indeed, there is, in such a circumstance, no expenditure of mechanical force at all. To make use of a very obvious illustration: if steam of the ordinary working pressure be generated in the boiler of a steam engine; then, so long as every passage from the boiler is closed, the steam, being thereby entirely confined, will constantly press with the same intensity upon the interior surface of the boiler, without any expenditure of its working force taking place. In short, the exertion of mere pressure might exist for ever undiminished. But, if a communication be established with the interior of the cylinder, then the steam by its pressure *moves* the piston from one end of the cylinder to the other, and in doing so it expends its elasticity in developing labouring force, or *moving pressure;* now we all know that the steam which fills the cylinder never returns to the boiler as it came from it, but, having done its duty, is discharged into the condenser or the atmosphere as the case may be.

The mechanical agents employed as sources of power must therefore be such that when in motion they continue to exert pressure; and the labouring force they can develop, or the work which they can do, must depend upon the pressure which they thus exert while they are in motion. When a man turns a heavy wheel, he exerts a certain pressure on the wheel when it is already in motion, and in order to continue this pressure, he has to follow the motion of the wheel with his hand. In like manner, in a steam engine the steam follows up the piston which it sets in motion, and continues to exert an undiminished pressure upon it. When motion is produced by a weight, as in the case of an ordinary clock, its effect is not in the least diminished by the motion of the machine, when the motion is uniform.

Characteristics of Labouring Force.—It may be understood, then, from what has been said, that the work done by any force applied uniformly, may be represented as a certain pressure exerted through a certain space. In what follows, it will be convenient, and indeed necessary, for the purpose of perspicuity, in speaking of pressure, to express it in terms of weight. Any pressure, for example, which is equal to the pressure caused by a weight of 6 lbs. on a cord by which it is suspended, may, irrespective of its origin, be said to be equal to a force of 6 lbs. In like manner, the space through which the pressure operates, is spoken of as the height through which the weight is raised. *Labouring force may, therefore, be measured by a given weight raised through a given vertical space.*

Thus, if it requires a force of 100 pounds to draw a carriage along a road, the labouring force expended in drawing this carriage over a distance of 20 feet, may be measured by the labouring force which would raise a weight of 100 pounds 20 feet high.

We have seen then that all labouring force is expressible by weight raised through space, whatever be the nature of the work done; it is not increased or diminished by any intermediate machinery, nor by any rate of working which does not diminish the pressure exerted by the moving or labouring force. Now, the work done is clearly doubled if the height through which the weight is raised be doubled, that is, if 6 lbs. be raised through 10 feet, the work done is doubled if the weight be raised through 20 feet altogether, as it is equivalent to raising other 6 lbs. through 10 feet. In like manner, twice the work is performed if twice the weight be raised through the same space, that is, having raised 6 lbs. through 10 feet, if we raise 12 lbs. altogether through the same height, it is equivalent, as before, to raising other 6 lbs. through 10 feet. Whether, then, the weight or the space be doubled, the effect will also be doubled. In short, it is clear that to whatever extent the weight or the space is increased or diminished, to the same extent will the work done be increased or diminished. Or, in general,

The labouring force varies proportionally as the resistance which is to be overcome.

And, the labouring force varies proportionally as the space through which the resistance has to be overcome.

* "In our towns in which large manufactories exist, such establishments often generate by their machinery more labouring force than they need; and the surplus (transferred by an axis, or in some other way, to a distance) is hired by other persons, and employed for the purposes of the most various kinds of work. In such towns, we often read advertisements of power to be disposed of to a large amount. The *power* here spoken of is labouring force.' —*Whewell: Mechanics of Engineering.*

Unit of Labouring Force.—To determine, therefore, the values of labouring force of various kinds, the *unit* or *common measure* of labouring force must be established, for which we may take a given weight raised through a given space. *One pound raised through one foot,* is the most general and convenient measure, and will be adopted in this article as the *dynamical unit* of labouring force. For the sake of abreviation we may read it *dynam,* as suggested by Whewell.

Measure of Labouring Force.—If one pound be raised through 10 feet, the labouring force expended, must, according to our definition, be equal to 10 units. If two pounds be raised through 10 feet, the labouring force must contain *twice* 10, or 20 units. And, in like manner, 6 pounds raised through 10 feet, required 6 times 10, or 60 units of labouring force. It is clear, therefore, that the labouring force required to move a certain weight through a certain height, will be expressed in units by the product of the weight in pounds, and the height in feet. Therefore, generally,

Labouring force is measured by the product of the resistance and the space through which it is overcome.

This conclusion is also at once derivable from what was said before. For, if the labouring force is proportional to the resistance, and likewise to the space, it must be proportional to the resistance and the space jointly, and may therefore be represented, by the product of the numbers representing these quantities.

Illustrations of Labouring Force.—It is clear, then, that to raise 6 pounds through 10 feet, and to raise 10 pounds through 6 feet, equal amounts of labouring force are required; as in both cases the latter is equal to 6×10 or 60 dynams. It is also the same thing as regards expenditure of force, whether 1000 pounds be raised through 1 foot, or 1 pound be raised through 1000 feet. If again, we have weights amounting to 100 pounds at the top of a building 100 feet high, these weights, if deprived of support, have the power of descending through 100 feet, either in one mass or separately. They may, therefore, by the intervention of machinery, be made to raise certain weights through corresponding heights. On a general view, it is obvious that the whole amount of work thus done cannot exceed 100×100 or 10,000 dynams; and it may be expended in raising either 10,000 pounds 1 foot high, or 1 pound 10,000 feet high, or 10 pounds 1000 feet high, and so on, the corresponding weight and height being always such that their product is equal to 10,000, the labouring force.

The labouring force exerted by a horse which draws a load of 6 cwt. over 2 miles of level road, is the same with that of a horse which draws 4 cwt. over 3 miles. To prove this, it is not necessary, as a preparatory step, to reduce the hundredweights and miles into pounds and feet, as the exertion of a force of 1 cwt. through the space of 1 mile, may, if convenient, be chosen for the unit of labouring force. On this supposition then, the labouring force is in the first instance represented by 6×2, or 12. In the second instance, it is 4×3, which is likewise 12: showing that the labouring force is the same in both cases. This equality may perhaps be rendered more obvious thus: the effect of 6 cwt. drawn over 2 miles is the same as that of 12 cwt. over 1 mile; for whether 2 horses draw each 6 cwt. over the same mile, or draw these over 2 successive miles, the same amount of effect is evidently produced. By exactly the same reasoning, it is evident that the effect of 4 cwt. drawn over 3 miles, is the same as that of 12 cwt. over 1 mile. Both of these effects being therefore equal to 12 cwt. drawn over 1 mile, they must be equal to one another.

Again, the effect of a weight of 4 cwt. in impelling or resisting the motion of a machine through 10 feet, is to that of a weight of 5 cwt., acting through 12 feet, as 2 to 3; for the product of 4 by 10 is 40, and the product of 5 by 12 is 60; now, 40 is to 60 in the ratio of 2 to 3.

The necessity of time as a measure of power.—Hitherto we have made no allusion to the element of time in the production of labouring force. But this element must obviously be taken into consideration in estimating the *rate* or *rapidity* with which labouring force is generated and expended; and it is equally necessary to be taken into account in comparing the capabilities of different sources of power. If we leave out of consideration the time required for an operation, all sources of power may be viewed as equally efficient. The mouse, for example, which exerts its strength in turning its revolving cage, for the purpose, we may suppose, of winding a thread, will exert any given amount of labouring force, equally with the horse labouring in the service of man, *there being no limit as to the time required for its performance.** The instant, however, that time is taken into account, the equality of the mouse and the horse, as sources of power, is destroyed, clearly because, *within any given time,* the latter is capable of doing a much greater amount of work than the former.

Now, the necessity of taking into account the time required for the execution of any given amount of work is quite apparent when we remember the value of time in every occupation of life. The time required for the fulfilment of any piece of work is always a matter of importance, and being so, the value of a source of power is enhanced in proportion to the rate with which it can put forth its labouring force. This leads us to notice that labouring force may be developed at the same rate, by the exertion of different degrees of pressure, provided that the relative velocities with which the pressures operate are inversely as the pressures themselves. Thus, suppose a horse walking along a level way, exerting its strength in raising a weight of 200 pounds, by means of a rope passing over a pulley, at a velocity of $2\frac{1}{2}$ miles per hour; if a weight of 100 pounds be drawn up with double the velocity, or 5 miles per hour, the work which will be performed in a given time will always be the same in both instances, for though in the second case there is raised only half the weight that is raised in the first case, yet on the other hand it is moved with twice the velocity; from which it is clear that while a load of 200 pounds is being raised through a certain height, two loads of 100 pounds each can be raised in the same time.

Since, therefore, the time required for the execution of a given amount of work, is a necessary element for determining the capabilities of any source of power, it follows that for this purpose three elementary data must be given, namely, pressure, space, and time. A common unit of time being fixed upon, of course the *velocity* of the pressure is expressed by the space described in that time, and, therefore,

The product of the pressure and its velocity will be the labouring force developed in a unit of time.

This alone affords an index to the power of the agent employed, and is the means of comparing it with the power of other agents.

We reserve for a future article the practical application of the principles above explained to the various mechanical powers employed in the service of man.

PRINCIPLES OF ALGEBRA.

CHAPTER IX.

ON EXPONENTS.

83.—*Integral Exponents.*—It has already been explained that when the same quantity is employed any number of times as a factor, the product is called a POWER of that quantity. The frequency with which such products occur has led to the introduction of the notation exhibited in the following table; it consists in writing over the letter raised to any power, on the right, a figure expressing the number of times it is employed as a factor, thus;

Operation.	Product	Written	Commonly called
x, x	xx	x^2	The square or second power of x
$x.x.x$	xxx	x^3	The cube or third power of x
$x.x.x.x$	$xxxx$	x^4	The fourth power of x
$x.x.x.x.x$	$xxxxx$	x^5	The fifth power of x

and so on. Here 2, 3, 4, 5, are called *exponents* of x, and show the number of times that x is employed as factor, or the order of the power; and by analogy x is called the first power of x, and may be written x^1. The powers of compound quantities are denoted in the same way;

$$\text{Thus}: (a+b)\times(a+b) \text{ is written } (a+b)^2$$
$$(a+b)\times(a+b)\times(a+b) \quad . \quad . \quad . \quad (a+b)^3$$

and so on. The following forms of expression should be studied, as showing the distinction between exponents and coefficients:

$$4x^3y^2z = xxxyyz + xxxyyz + xxxyyz + xxxyyz$$
$$4xy^2z^3 = xyyzzz + xyyzzz + xyyzzz + xyyzzz$$
$$4x^2 - 3x^3 + 2x^4 = 4xx - 3xxx + 2xxxx$$
$$(x+y)(x-y) = x^2 - y^2 \quad (x-y)^3 = x^3 - 3x^2y + 3xy^2 - y^3$$

* An extravagant example of the neglect of *time* occurs in the famous conclusion of Archimedes, when he discovered the properties of the lever: "Give me a place to stand upon, and I will move the world." The principle on which his conclusion was founded was undeniable, and his calculation was perfectly correct, if indeed he ever set about the calculation; but it is clear he had no conception of the *time* requisite to give so huge a mass any appreciable motion by means of a lever, moved by so small a force as could have been supplied by the arm of Archimedes. It has been calculated that to have moved the earth one inch, on the supposition of its gravitating towards some other mass of matter, as a stone does to the earth, would have required the continual labour of Archimedes, most economically applied, for the time of 8,774,994,500,737 centuries.

84. Let it be required to multiply a^3 by a^2. By definition,

$$a^3 = aaa \qquad a^2 = aa$$

$$\text{but } aaa \times aa = aaaaa = a^5$$

$$\therefore a^3 \times a^2 = aaa \times aa$$

$$= a^5 \text{ or } a^{3+2}$$

where the exponent of the product is the sum of the exponents of the factors. From this and similar operations we derive the following

RULE. *To multiply together any two powers of the same letter, make the exponent of the product the sum of the exponents of the factors.*

EXAMPLES. $x^2 \times x^3 = x^5 \qquad x^4 \times x^3 = x^7$

$ax^3 \times x^5 = ax^8 \qquad abx^7 \times x^2y^2 = abx^9y^2$

The rule also applies when there are more than two factors; for

$$x^2 \times x^3 \times x^5 \times x^4 = (x^2 \times x^3) \times (x^5 \times x^4) = x^5 \times x^9 = x^{14}$$

$$7a^2b^6 \times 3a^2b^2c^3 \times 7a^4x \times 3b^3x^2 \times 5cx^2y^3 = 2205a^8b^{11}c^4x^5y^3$$

85. Let it be required to divide a^7 by a^3. Since $7 = 4 + 3$, or since $a^7 = a^4 \times a^3$; therefore $a^7 \div a^3$ or $\frac{a^7}{a^3}$ is a^{7-3} or a^4. Hence we have the following

RULE. *To divide the power of a quantity by another power of the same quantity (of a less exponent) subtract the exponent of the divisor from the exponent of the dividend.*

EXAMPLES. $a^5 \div a^2 = a^3 \qquad a^7 \div a^6 = a^1$ or a

$10a^7 \div 5a^4 = 2a^3 \qquad 7x^2 \div 14x = \frac{1}{2}x$

$$\frac{24a^6b^4c^4d^2}{4a^4b^2c^3d} = 6a^2b^2cd \qquad \frac{3a^2p^3q^4x^2z^3}{6ap^2q^2xz^2} = \tfrac{1}{2}apq^2xz$$

86. *Anomaly* 1. By the rule above, $a^m \div a^n = a^{m-n}$. But if $m = n$ then $a^{m-n} = a^0$, a new and unexplained symbol. Returning to the original operation, we find that we are required to divide a quantity by itself. The answer is therefore manifestly 1; for, on the supposition $m = n$,

$a^m \div a^n$ becomes $a^m \div a^m = a^{m-m} = a^0$; but $a^m \div a^m = \frac{a^m}{a^m} = 1$

whatever may be the values of a and m. It therefore appears that *any letter having the exponent* 0 *may be regarded as* UNITY, or in conformity with the notation adopted, *any quantity raised to a power whose exponent is* 0, means 1, and may be replaced by 1.

87. *Anomaly* 2. Let $a^m \div a^n = a^{m-n}$ and let m be less than n, or let $n = m + 2$, then

$a^m \div a^n$ becomes $a^m \div a^{m+2}$, that is, $a^{m-(m+2)} = a^{-2}$,

another unexplained symbol. But observing that a^{m+2} is $a^m \times a^2$, we have

$$a^m \div a^{m+2} = \frac{a^m}{a^m \times a^2} = \frac{1}{a^2}$$

We therefore agree that a^{-2} shall stand for $1 \div a^2$. And similarly, according to this convention, we have

$$1 \div x = \frac{1}{x} = x^{-1} \qquad 1 \div x^p = \frac{1}{x^p} = x^{-p}$$

From these and similar instanees we lay down this definition: *a letter having a negative exponent means unity divided by that letter with the same numerical exponent taken positively.* The following are instances of the application of these two conventions:—

$x^6 \div x^6 = x^0 = 1$	$a^mx^6 \div a^mx^3 = a^0x^3 = x^3$
$a^2x^3 \div ax^3 = ax^0 = a$	$a^3b^2c^5 \div a^3c^4 = b^2c$
$a^3x^3 \div a^3x = a^0x^2 = x^2$	$a^3d^2x^2 \div d^2x = a^3x$
$\frac{x^2}{x^6} = \frac{x^2}{x^2x^4} = \frac{1}{x^4} = x^{-1}$	$\frac{x^{10}}{x^{18}} = \frac{x^{10}}{x^{10}x^8} = \frac{1}{x^8} = x^{-8}$
$\frac{x^3}{x^9} = \frac{x^3}{x^3x^6} = \frac{1}{x^6} = x^{-6}$	$x^5 \div x^{11} = x^{-66} = \frac{1}{x^6}$

88 The following instances show that our rules for multiplication and division are general, and apply equally where the exponents are negative. In the first column are the common processes, and in the second, the extensions explained:—

$\frac{1}{x^3} \times x^4 = \frac{1}{x^3} \times \frac{x^4}{1} = x$	$x^{-3} \times x^4 = x^{-3+4} = x^{+1}$ or x
$\frac{1}{x^3} \div \frac{1}{x^4} = \frac{1}{x^3} \times \frac{x^4}{1} = x$	$x^{-3} \div x^{-4} = x^{-3-(-4)} = x^{-3+4} = x$
$x^3 \div \frac{1}{x^2} = x^3 \times x^2 = x^5$	$x^3 \div x^{-2} = x^{3-(-2)} = x^{3+2} = x^5$
$\frac{1}{x^3} \div x^4 = \frac{1}{x^3} \times \frac{1}{x^4} = \frac{1}{x}$	$x^{-3} \div x^4 = x^{-3-(+4)} = x^{-3-4} = x^{-7}$

89. *Powers and Roots.* By a *root* of any quantity is meant the inverse of a *power* of that quantity: for instance, if p be a power of r, then r is a root of p. The following table will render the relative meaning of the terms familiar.

Name of p	Conditions fulfilled	Name of r	Conditions fulfilled.
Square of r	$p = rr$ or r^2	Square root of p	rr or $r^2 = p$
Cube of r	$p = rrr$ or r^3	Cube root of p	rrr or $r^3 = p$
Fourth power of r	$p = rrrr$ or r^4	Fourth root of p	$rrrr$ or $r^4 = p$
Fifth power of r	$p = rrrrr$ or r^5	Fifth root of p	$rrrrr$ or $r^5 = p$

and so on. The operation by which we find p from r, that is, a power from its root, is called *involution;* and the operation by which we find r from p, that is, a root from its power is called *evolution.* These operations are therefore the inverse of each other.

90. From (Art. 84.) we have this rule for multiplication,

$$x^m \times x^n \times x^p \times x^q = x^{m+n+p+q}$$

which holds for all values of m, n, p, q. If then $m = n = p = q$, we have manifestly $m + n + p + q = 4m$, and consequently

$$x^{m+n+p+q} = x^{m+m+m+m} = x^{4m}$$

which is the fourth power of x^m. Hence this

RULE. *To raise a power of a monomial* X, *to any given power, multiply the exponent of the proposed quantity* X, *by the exponent of the proposed power:* the result is the exponent. Thus;

The fourth power of x^2 is $x^{2\times4} = x^8 =$ for $(x^2)^4 = x^2 \times x^2 \times x^2 \times x^2$.

$(x^3)^2 = x^6 \qquad (x^2)^5 = x^{10} \qquad (x^4)^5 = x^{20} \qquad (x^4)^2 = x^8$

$(x^2)^n = x^{2+2+2+\text{\&c. to } n \text{ terms}} = x^{2n} \qquad (x^m)^n = x^{mn}$

Also: *A power of a product is the product of the factors severally raised to the power proposed.*

$$\text{Thus: } (xyz)^3 = xyz.xyz.xyz = xxxyyyzzz = x^3y^3z^3$$

$$(x^2y^3z^4)^3 = x^2x^2x^2\,y^3y^3y^3\,z^4z^4z^4 = (x^2)^3(y^3)^3(z^4)^3 = x^6y^9z^{12}$$

$$(x^my^nz^p)^r = (x^m)^r(y^n)^r(z^p)^r = x^{mr}\,y^{nr}\,z^{pr}$$

The same rule may be applied to fractional quantities.

$$\text{Thus: } \left(\frac{x}{y}\right)^3 = \frac{x^3}{y^3} \text{ for } \left(\frac{x}{y}\right)^3 = \frac{x\ x\ x}{y\ y\ y} \text{ and } \frac{x^3}{y^3} = \frac{xxx}{yyy}$$

$$\left(\frac{a^2b^4}{xy^3}\right)^2 = \frac{a^4b^8}{x^2y^6} \qquad \left(\frac{ab^2c^3}{x^3y^2z}\right)^4 = \frac{a^4b^8c^{12}}{x^{12}y^8z^4}$$

91. The extraction of roots is denoted arithmetically by $\surd$ called the *radical sign.** Its use is shewn in the following table:

The 2nd root of x is $\sqrt{x}$,	of x^2 is $\sqrt{x^2}$,	of $\sqrt{x}$ is $\sqrt{\sqrt{x}}$
The 3rd root of x is $\sqrt[3]{x}$,	of x^4 is $\sqrt[3]{x^4}$,	of $\sqrt{x^2}$ is $\sqrt[3]{\sqrt{x^2}}$
The 4th root of x is $\sqrt[4]{x}$,	of x^3 is $\sqrt[4]{x^3}$,	of $\sqrt[2]{x}$ is $\sqrt[4]{\sqrt[2]{x}}$
The 5th root of x is $\sqrt[5]{x}$,	of x^m is $\sqrt[5]{x^m}$,	of $\sqrt[n]{x}$ is $\sqrt[5]{\sqrt[n]{x}}$

and so on: observing that $\sqrt{x}$ means $\sqrt[2]{x}$, the index† 2 being usually omitted. We shall make use of this notation in the meantime.

92. What is the *third* root of x^6? *Ans.* $\sqrt[3]{x^6} = x^{\frac{6}{3}} = x^2$.

Because $(x^2)^3 = x^6$. (See Art. 89.) We have therefore this

RULE. *To extract a root of a power of any monomial* X, *divide the exponent of the power by the index of the root, if that division can be effected without introducing fractions.*

If there be a numerical coefficient, its root must be extracted as in common arithmetic.

$$\text{Thus: } \sqrt{16x^4y^2} = 4x^2y \qquad \sqrt[4]{81a^{12}b^4c^8} = 3a^3bc^2$$

$$\sqrt[3]{343a^3x^9y^6z^{12}} = 7ax^3y^2z^4 \qquad \sqrt[5]{32a^{10}x^5y^{15}} = 2a^2xy^3$$

93. We shall now premise the following propositions:

I. *The root of a root has the product of the indices of these roots for its index.*

Let $\sqrt[3]{\sqrt[4]{X}} = x$ Then $\sqrt[4]{X} = x^3$ $X = (x^3)^4 = x^{12}$

$\therefore x = \sqrt[12]{X}$ But $x = \sqrt[3]{\sqrt[4]{X}}$ $\therefore \sqrt[3]{\sqrt[4]{X}} = \sqrt[12]{X}$

* The mark $\surd$ is derived from the letter r, the initial of *radix* or *root.* When used alone, it denotes the second or square root.

† The figure denoting the order of the power is called the *exponent;* the figure denoting the order of a root, is called the *index.* This distinction however is not always attended to, nor is it indeed, as we shall afterwards see, at all necessary.

Similarly, $\sqrt[3]{\sqrt{x}} = \sqrt[6]{x}$ $\sqrt[3]{\sqrt{\sqrt{x}}} = \sqrt[12]{x}$

$\sqrt[5]{\sqrt[3]{\sqrt[4]{v}}} = \sqrt[60]{v}$ $\sqrt[a]{\sqrt[b]{x}} = \sqrt[ab]{x}$ $\sqrt[m]{\sqrt{ax}} = \sqrt[2m]{ax}$

Conversely, Since $\sqrt[a]{\sqrt[b]{x}} = \sqrt[ab]{x}$ and $\sqrt[b]{\sqrt[a]{x}} = \sqrt[ab]{x}$

$\therefore \sqrt[ab]{x} = \sqrt[a]{\sqrt[b]{x}} = \sqrt[b]{\sqrt[a]{x}}$

$\sqrt[20]{x} = \sqrt[10]{\sqrt{x}} = \sqrt[5]{\sqrt[4]{x}} = \sqrt[5]{\sqrt{\sqrt{x}}}$ $\sqrt[16]{x} = \sqrt{\sqrt{\sqrt{\sqrt{x}}}} = \sqrt[4]{\sqrt[4]{x}}$

II. *The root of a product is equal to the product of the roots of the factors.*

Thus: $\sqrt[3]{abc} = \sqrt[3]{a} \times \sqrt[3]{b} \times \sqrt[3]{c}$ for $(\sqrt[3]{abc})^3 = abc$

$(\sqrt[3]{a} \times \sqrt[3]{b} \times \sqrt[3]{c})^3 = (\sqrt[3]{a})^3 \times (\sqrt[3]{b})^3 \times (\sqrt[3]{c})^3 = abc$

that is, both $\sqrt[3]{abc}$ and $\sqrt[3]{a} \cdot \sqrt[3]{b} \cdot \sqrt[3]{c}$ are cube roots of abc; but abc can have only one arithmetical cube root, therefore $\sqrt[3]{abc}$ and $\sqrt[3]{a} \cdot \sqrt[3]{b} \cdot \sqrt[3]{c}$ are identical.

Similarly $\sqrt{abc} = \sqrt{a} \cdot \sqrt{b} \cdot \sqrt{c}$ $\sqrt[3]{a^2b^4c^5} = \sqrt[3]{a^2} \cdot \sqrt[3]{b^4} \cdot \sqrt[3]{c^5}$

$\sqrt[3]{24} = \sqrt[3]{8} \times \sqrt[3]{3} = 2\sqrt[3]{3}$. $\sqrt[4]{32} = \sqrt[4]{16} \times \sqrt[4]{2} = 2\sqrt[4]{2}$

The same rule is applicable in division. Thus: $\sqrt[3]{\frac{a}{b}} = \frac{\sqrt[3]{a}}{\sqrt[3]{b}}$

For $\sqrt{\frac{a}{b}} \cdot \sqrt{\frac{a}{b}} = \frac{a}{b}$ and $\frac{\sqrt[3]{a}}{\sqrt[3]{b}} \cdot \frac{\sqrt[3]{a}}{\sqrt[3]{b}} \cdot \frac{\sqrt[3]{a}}{\sqrt[3]{b}} = \frac{a}{b}$

Similarly: $\sqrt[n]{\frac{ab}{xy}} = \frac{\sqrt[n]{ab}}{\sqrt[n]{xy}} = \frac{\sqrt[n]{a} \cdot \sqrt[n]{b}}{\sqrt[n]{x} \cdot \sqrt[n]{y}} = \sqrt[n]{\frac{a}{x}} \times \sqrt[n]{\frac{b}{y}}$

III. *When a power of* x *is raised, and a root of that power extracted, the result is not altered by changing the order of the operations.*

Thus: $\sqrt[3]{a^2}$ is the same thing as $(\sqrt[3]{a})^2$

For $a^2 = a.a$ $\therefore \sqrt[3]{a^2} = \sqrt[3]{a} \cdot \sqrt[3]{a}$ which is $(\sqrt[3]{a})^2$

Similarly. $\sqrt[3]{a^4} = \sqrt[3]{aaaa} = \sqrt[3]{a}\sqrt[3]{a}\sqrt[3]{a}\sqrt[3]{a} = (\sqrt[3]{a})^4$

$\sqrt[n]{a^m} = (\sqrt[n]{a})^m$ $\sqrt[4]{a^3b^3} = (\sqrt[4]{ab})^3$ $\sqrt{a^3b^6} = (\sqrt{ab^2})^3$

IV. *In the expression* $\sqrt[n]{a^m}$, *if* n *and* m *be both multiplied or both divided by the same number, the value of the expression is not altered.*

That is, $\sqrt[n]{a^m} = \sqrt[np]{a^{mp}}$

For $\sqrt[np]{a^{mp}} = \sqrt[n]{\sqrt[p]{a^{mp}}}$ which is $\sqrt[n]{\sqrt[p]{(a^m)^p}} = \sqrt[n]{a^m}$

Because $a^{mp} = (a^m)^p$ and $\sqrt[p]{(a^m)^p} = a^m$ by III.

Similarly, $\sqrt[3]{x^2} = \sqrt[9]{x^6} = \sqrt[6]{x^4} = \sqrt[15]{x^{10}} = \sqrt[3n]{x^{n2}}$

$\sqrt[12]{a^6} = \sqrt{a}$ $\sqrt[14]{a^7b^{21}} = \sqrt{ab^3}$ $\sqrt[5]{ab^3} = \sqrt[10]{a^2b^6}$

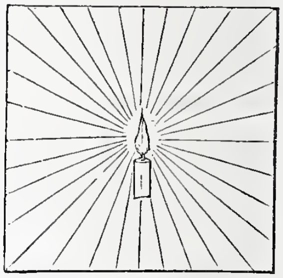
ON THE PRINCIPLES OF LAMP REFLECTORS.

BY MR. JOHN HART.

The construction of reflectors in a proper manner for economising or concentrating the light of the lamps which are now extensively employed for purposes of illumination and signal lights, is a subject which, to the operative mechanic, who is not conversant with the principles of geometrical constructions, must always be a source of perplexity, especially if he be engaged in their construction. My principal design in the following paper is to remove the difficulties on this score out of the way of the unscientific mechanic. With this view I have aimed at treating the subject in as plain and familiar a manner as possible, by means of the most obvious illustrations, occasionally referring to the analogous subject of sound. And, while I aim principally at simplifying the subject to those who are but little acquainted with geometrical illustration, I hope the following article will not be uninteresting to the more intelligent reader.

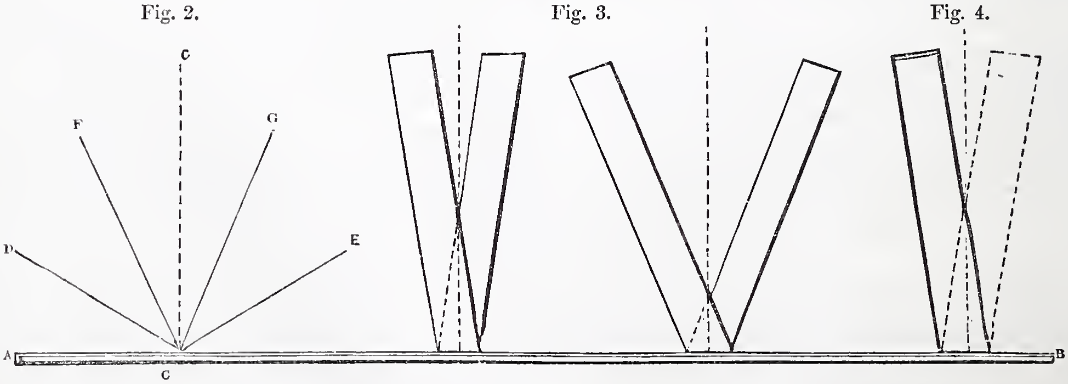
While engaged in drawing a curve, as a gauge to enable the workmen to form the reflectors of the lamps for illuminating the dials of the Tron Steeple of Glasgow, it occurred to me that a simple method might be adopted of constructing these curves without the aid of instruments altogether, and by a much simpler operation than any of the methods usually practised. Thus, upon a sheet of paper, (fig. 1), let a number of radii be drawn from a centre, to represent rays of light diverging from a luminous body; if we fold over any number of these radii in the direction in which the light is destined to be reflected, the succession of folds will represent the plane of the reflecting surface necessary to produce the given reflection, because both portions of the ray must necessarily be at equal angles to the fold. On applying this idea I found it to answer perfectly, and I then saw that by this simple operation I could readily produce surfaces that would reflect the light in any direction which might be required, and that it would also afford a means of mechanically illustrating the properties of the conic sections and other curves, as reflecting surfaces for light and sound.

Fig. 1



We are informed that heat, light, and in many cases sound, obey the same law which governs the motions of a ball when thrown against a wall, or upon a smooth pavement, that is, at whatever angle with the perpendicular they strike the reflecting surface, they rebound, or are reflected, at an equal angle with the perpendicular. Thus, let A B, (fig. 2), be a plane surface, and C C, a perpendicular to that surface; then, if the ball strikes, or if the incident ray, as it is called, of heat, light, or sound, proceeds in the direction of D C, it will rebound, or will be reflected from C to E, the angle D C C being equal to C C E; or, if the incident ray move in the direction of F C, the reflected ray will go off at equal angles in the direction C G, and so on. If we take a slip of paper, and fold it, as in fig. 3, it will give a much more correct idea of the angle of incidence and reflection being equal to one another, than the diagram of lines, especially if it be again folded together, so as to make the two legs of the slip coincide, as in fig. 4; the crease produced by the fold will be a perpendicular to the reflecting surface, and the incident and reflected rays will be at equal angles to this perpendicular, at whatever inclination the incident ray may strike. This experiment is very easily made, and if a slip of paper be folded into various angles, and held up to the light, in every case the

Fig. 2. Fig. 3. Fig. 4.



crossing of the strips will be perceived, forming a triangle, or two right-angled triangles, on each side of the perpendicular; thus clearly showing that the beam of light, the wave of sound, the ball thrown from the hand, or impelled by the mace of the billiard player, or even discharged from a musket against a flat surface at any of these angles will rebound, and proceed onward in the direction of the other leg. Having been satisfied with this, what follows will appear plain and easy, because founded upon this principle alone.

Fig. 5.

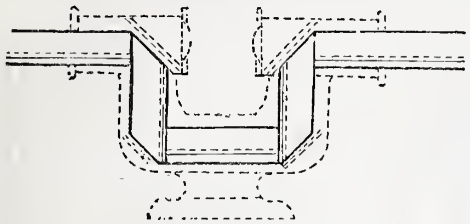


Fig. 5, shows an exemplification of the principle now explained in the construction of the optical toy, the Palemoscope; the slip of paper represents the path of the light proceeding from an image, and the folds the angles of the mirrors by which the light is reflected round the bend of the instrument. If two or three lines be drawn along one edge of the paper, as shown in the figure, they will explain how the image is inverted by the first reflection, and again becomes erected after the second.

Fig. 6, represents the two folds or reflections containing a right angle, and composing an erected image, in that beautiful little instrument the Camera Lucida of Dr. Wollaston. The folds represent the angles of the prism, and the lines also show how the object becomes inverted by the first, and again erected by the second reflection. I shall now proceed to apply the mode of illustration just explained to the formation of reflectors of different curvatures. I shall begin with the most simple.

Fig. 6.

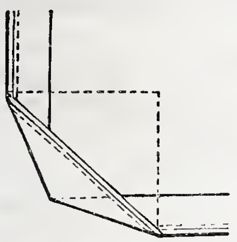
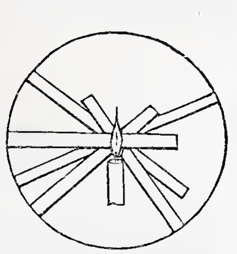


Fig. 7.



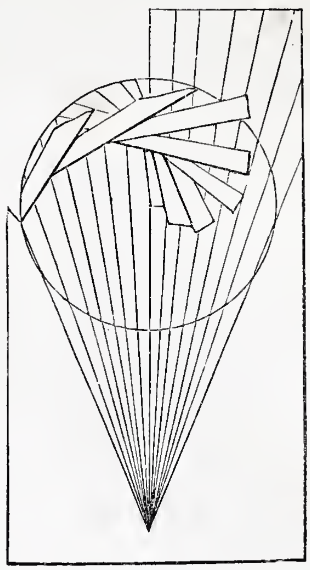
Of the Circle.

It is a well-known optical fact, that rays of light falling upon a spherical surface, from a luminous body placed in any point except the centre, will not meet in a point after reflection, but will converge into a number of distinct foci from every part of the circle. If a line be drawn through these foci, it constitutes what is called a caustic curve. To illustrate this, having described a circle (fig. 7), take a narrow slip of paper, and fix one end of it with a pin in the centre of the circle, then fold it over upon any part of the circumference, it will be found always to return to the centre again. Now, take two sheets of paper, as figs. 8 and 9: upon one of them draw a series of parallel lines, 1-4th of an inch asunder, and upon the other a series of diverging lines; from a point about the middle of each describe a circle upon both sides of the paper, and with a knife slit up the paper along every alternate line, commencing a little within the circumference of the circle; these lines will represent parallel and diverging rays of light. Fold over the stripes upon the circumference of the circle, and it will be seen that these rays do not meet in a point, but cross each other, and form by their intersections what we have already alluded to as the caustic curve. This clearly shows that a circular surface, or a portion of a sphere, is not a proper form for a reflector, unless the reflected light be required to radiate as if issuing from the flame itself.

Of the Ellipse.

If a luminous, or a sounding body, be placed in the focus of an ellipse, the rays of light or sound will be reflected upon the interior surface of the ellipse to the other focus; or, if a ball be discharged against the walls of an elliptical chamber, from one of the foci, it will rebound and strike an object in the other focus. This may be shown by laying a narrow slip of paper on one of the foci (fig. 10), and folding it at any place upon the curve; it will invariably point to the other focus. Again, by taking a few strips of paper, of equal lengths, and pushing a pin through the ends of them as a centre, and folding them so that the folds may follow on continuously, the other ends pointing to another centre, the folds will assume the form of an ellipse around these two centres: thus clearly shewing that every point of this curve will reflect the light or sound from the one focus to the other.

Fig. 8.



Of the Parabola.

If a luminous body be placed in the centre or focus of a parabola, the light will be reflected from the surface of this curve in parallel streams; or conversely, if parallel rays fall upon this surface, they will all be reflected to the focus of the curve. To demonstrate this, and also to show how far the parabola deviates from the circle, take a piece of paper, and having drawn a circle, and also a number of parallel lines upon it, as in fig. 9; push a sprig into the centre of the circle, then fold over the strips, beginning with the first fold upon the curve of the circle, and pushing the centre of the strip over the head of the sprig, as in fig. 11, fold over the rest, making each fold join the last, and thrusting the whole over the sprig, the curve produced will be a parabola, the sprig representing its focus, and the strips the path of the light before and after reflection, while the difference between the curves will at once become apparent by the contrast. Or, take half a sheet of paper, and fold it a number of times, producing, say sixteen creases or lines; if the centre represents a luminous point, a candle for instance, of course the lines will represent the rays of light radiating from it, as in fig. 1; make a slit between each line nearly to the centre; fold over one of the pieces, making the fold at the same distance from the centre as the focus of the curve is required to be; make the cress or centre line of this fold to return upon itself over the centre of the radii; fold over the rest, causing each successive fold to join with the last, and observing always to make the centre line of each fold parallel to the centre line, with which the operation was begun. The curve formed by these folds will be a parabola.

Of the Hyperbola.

If the pieces be so folded, or the lines made to diverge, so that if they were prolonged behind the curve they would meet in a point, the curve formed by the folds will be a hyperbola. Therefore, if a luminous body be placed in the centre of this curve, as in fig. 19,

the light will be reflected as if radiating from a point behind the curve, or from its vertical focus.

From the foregoing demonstrations it is evident that the spherical reflector cannot be used with advantage by itself; however, as flame is transparent, and does not materially obstruct the passage of other light through it, as may be seen by placing one flame behind another, when a lens is used in front of the flame, as the Fresnel lens in lighthouses, a spherical reflector of the size of the lens will considerably increase the intensity of the light without altering the inclination of the rays, which may be understood on examining fig. 21. However, as these large prismatic lenses are too weighty and too expensive for common purposes, the parabola, with a plain plate-glass in front, is much better adapted for general use, especially where a large luminous object is necessary, or a parallel stream of light is to be transmitted to a great distance at sea, or for signals upon railroads. Again, when the light is required to be transmitted to a considerable distance, and at the same time to be concentrated upon a small object, or to diverge after it passes a certain point, then it is evident the ellipse is the curve required, the luminous object being situated in one focus, and the body to be illuminated in the other focus.

Where the light is required to expand or spread, so as to illuminate a given space, the hyperbola is obviously the curve best adapted for the purpose, though the parabola also must cause the

Fig. 9.

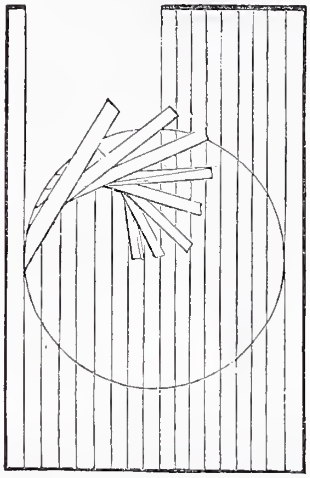


Fig. 10.

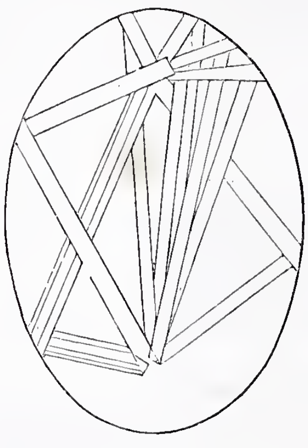
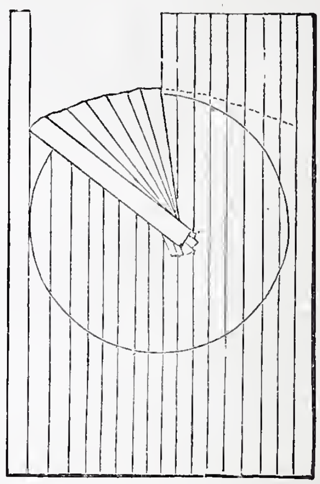


Fig. 11.



light to diverge to a limited extent, as the flame, of course, is always larger than the focal point of the curve; nay, even the ellipse is sometimes to be preferred for diverging rays, as by it the lamp may be made much smaller in size, and a much smaller glass will answer than if the hyperbola were used, which may be seen by referring to fig. 20.

Leaving the conic sections, let us attend to the more simple methods of forming reflecting surfaces, independent of these curves, by giving one or two examples of its application to acoustics.

Of the Speaking Trumpet.

A long strip of paper folded, as in fig. 12, will illustrate the necessary characteristic of the speaking trumpet, that is, the proper taper of the conical tube, so as to cause the last reflection to leave

Fig. 12.

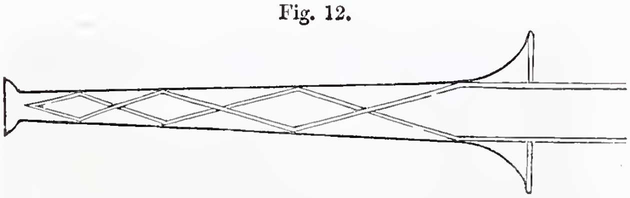
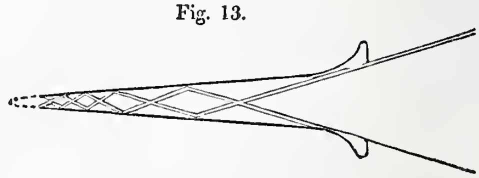


Fig. 13.



the instrument in a straight forward direction, or in parallel lines. The ear trumpet (fig. 13), is just the converse of this; it will be seen, by inspecting the figure, that the dotted part of the cone must be cut off, otherwise the greater part of the sound after another reflection would return.

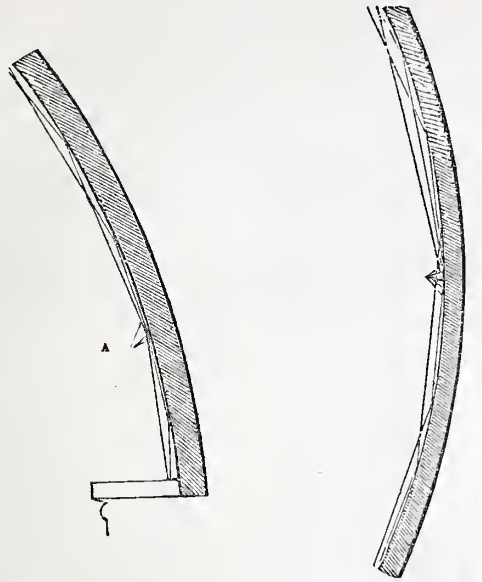
By drawing two or three converging lines and folding a slip of paper from side to side, as in fig. 12 or 13, a workman, unacquainted with geometry, may determine the proper angle for any trumpet of this kind, which he may be employed to make.

By the same means the phenomenon of the Whispering Gallery of St. Paul's may also be explained. Describe a circle, fig. 14, and take two or three narrow slips of paper; pushing a pin through them near the inner edge of the circle, to represent the voice issuing from the mouth of the speaker, fold them upon the curve until they reach the opposite side of the circle, it will now be seen how the wave of sound radiating in straight lines from the mouth of the whisperer at A, will be reflected from point to point, streaming along the surface of the dome, until it becomes again concentrated by meeting at the opposite side: just as in an elliptical building where the whisper of an individual placed in one of the foci, is distinctly heard by a person placed in the other. That sound travels along the surface of a hemispherical building in the manner now explained, is pretty evident, because the whisper becomes quite inaudible at two or three feet from the surface of the dome, and can be heard only when the ear is placed about the same distance from the reflecting surface as the mouth of the speaker, and consequently is in the direct line of the reflections.

I shall now describe a few applications of this principle in the construction of reflectors, that have occurred to myself. Shortly after the swift boats were introduced upon the Paisley and Johnston canal, my opinion was asked about the best means of lighting the bridges and towing path. I was shown two lamps they had just got, one of which was procured from one of the English canals, and the other was made in Glasgow. They stated that what they wanted was a lamp to concentrate the light and throw it forward in a stream of sufficient breadth at about 100 feet a-head of the boat, so that the man at the helm might see to port her safely through the arch. As both their lamps were simply large argands furnished with discs of tinplate slightly curved by way of reflectors, I told them that none of them would answer their expectations; neither did the persons who had constructed them seem to understand how these reflectors ought to be formed. I then took a sheet of packing paper, and pointing to two shops upon the opposite side of the street, observed to the parties who were with me, that supposing the lamps placed where we were standing, their object would be effected, if the stream of light could be made to illuminate a space equal in width to these two shops at about the same distance a-head of the boat. They having been satisfied of that, I then cut an angular strip off the edges of the sheet, so that when looking along the edges, the angle or divergence was equal to the space to be illu-

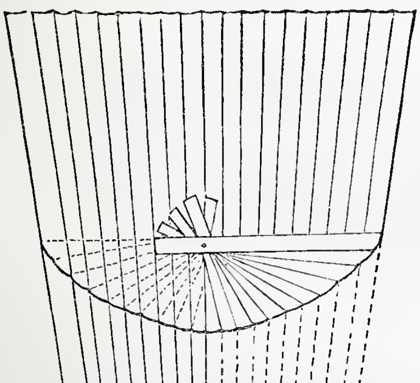
minated. Having folded and refolded it until it became like a closed fan by cresses of about three-fourths of an inch in breadth, I unfolded it, and spread it flat upon a table, and having placed a weight upon the two extreme corners to prevent its rising, and driven a

Fig. 14.



sprig of wire into the centre cress, where I supposed the flame of the argand to be situated, I made an incision between each cress as far as I thought the curve would extend. I then folded over the strips, making the first fold upon the centre strip, and at about three-fourths of an inch from the place of the argand glass; having folded over the rest, taking care always to make the folds join, and to push the centre cress of each strip over the head of the sprig, I completed the curve shown in fig. 15. Then I explained to those

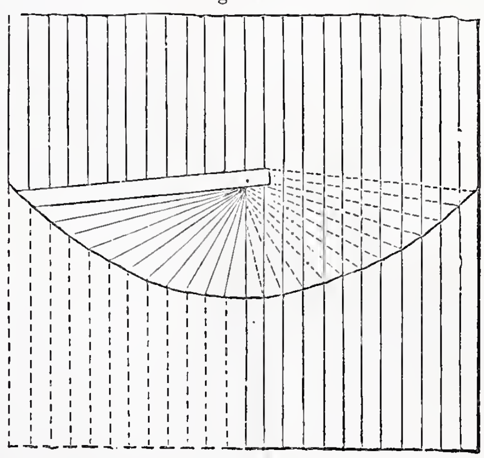
Fig. 15.



who were with me that the position of the sprig must be the place of the argand burner, and the curve the form of the reflecting surface, these strips representing the path of the light before and after reflection, the whole was so apparent that they immediately ordered a gage to be made from the curve, with which the lamp reflectors were to be formed. The reflector was tried and found to answer their purpose so completely that all the other lamps used upon the canal were fitted with similar reflectors.

That these processes are not without their use, even to philosophers and mathematicians, I may illustrate by the following occurrence. A learned Professor of Chemistry, from one of our northern universities, when in Glasgow, informed me he had been calling upon Professor Graham of the Andersonian University,* and had seen two very fine brass reflectors for experiments on heat that the Professor had lately procured from London. He asked if I thought it possible he could get such another pair constructed for him in Glasgow. I told him I thought so, as I knew of one who I believed could do them for him. He was at a loss, however, for want of his instruments to draw down the proper gage of the curve. I said I would manage that part of the process, as I could form the curve without any instruments. At this he smiled, and although an excellent mathematician, as well as a chemist, he thought it was impossible. However, we went to the workshop, and found the workman there. I then got a sheet of packing paper, and having folded and refolded it as in the former case, adapting it for a parabolic reflector, the paper was kept square and the cresses parallel to each other. (Fig. 16.) I then proceeded to fold it in the same way, passing all the cresses upon the strips over the

Fig. 16.



head of the sprig. In this case the diameter of the reflector was 21 inches, and the focus of the curve they were to be wrought to, 6 inches. Having completed the curve, I slipped in beneath the folds a half sheet of the same thick paper (having previously cut a notch in the middle of one edge to embrace the centre sprig), and with a pen traced the curve from the fold upon it; I then withdrew the paper, and with a knife cut the curve out, so that from it the workman might cut his guage of tinplate, from which he was to hammer up the reflectors. After they were completed, I tried one of them with the full rays of a December sun. It instantly pierced a slightly irregular hole of about one eighth of an inch, which I preserved as a curiosity to show the accuracy of his workmanship, and how correctly he had kept to the curve. Indeed his reflectors when finished were superior to those which were made in London, and gave such satisfaction as to induce other lecturers to supply themselves with reflectors made up to the same guage.

The foreman of a tinsmith's shop called upon me at the desire of his master: he said his master had been employed to fit up a lodging with pipes of communication between the different rooms, as it was now going to be converted into an office or place of business, and as, from the nature of the building, there would necessarily be a number of angles in their pipes, to render the sounds articulate they were told they must put in little oval plates (plates of an elliptical shape), at each of the angles. Now, what they were at a loss to know was, what length these elliptical plates should be, and how they were to be put into the angles, as they had never seen it done. I took a strip of paper about the same breadth as the diameter of his pipe, and made one or two folds upon it at different angles (see fig. 17), to represent the angles upon his pipe. I then pointed out to him, that the fold at the angles represented the length of the elliptical plates. As he did not seem to comprehend it clearly, I drew three parallel lines with ink along the strip, then folded it again and held it up to the light, to show him how each of the lines struck the flat plate, and were reflected along the other portion of the pipe. He now understood the thing clearly, especially when I folded the two legs of the strip together, to show the angle of the joint also; he had first to join the pipes at the proper angles, and having laid the strip of paper folded to the same angle upon the pipe, to mark the line of the reflector, and to cut off the piece with a file, and solder on a flat piece of tinplate.

* Now of the London University.

We may now consider the attentive workman, who has repeated these experiments by folding the papers for himself, as being perfectly master of the principle, and competent to construct a reflector fitted for any purpose. Before leaving this subject altogether, I shall present him with a few sketches of finished lamps, to show how they have been fitted up.

Fig. 17.

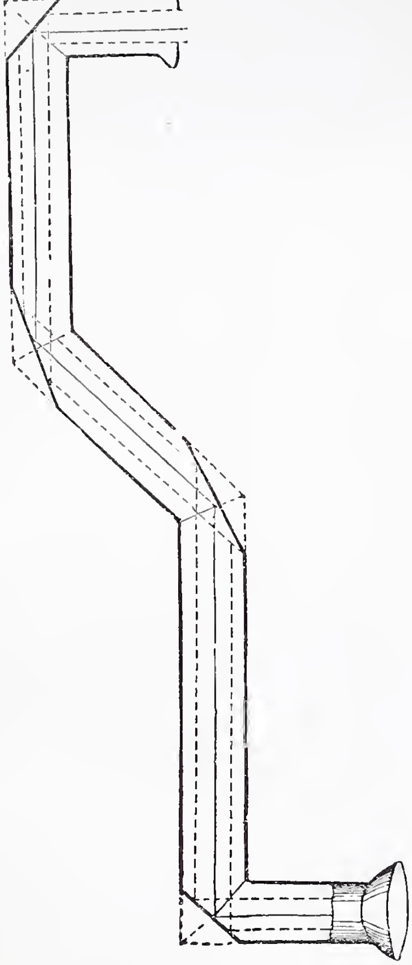


Fig. 18, a ship-lantern having an argand lamp, with a parabolic reflector, of about 14 inches diameter for the purpose of transmit-

Fig. 18.

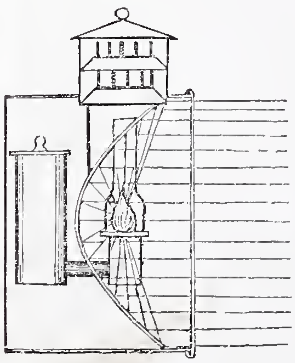
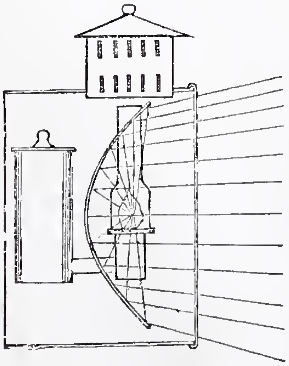


Fig. 19.

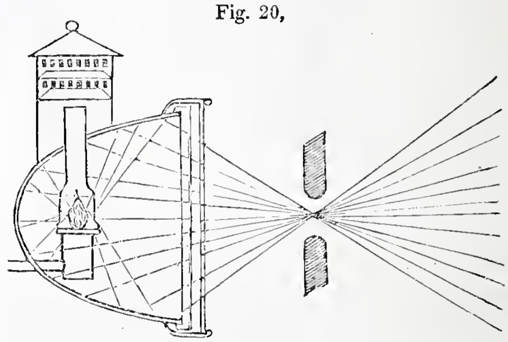


ting the light in a parallel stream to a great distance, similar to those used in the lighthouse. The oil-cistern is shown behind the reflector; an opening of course must be made in the lower portion of the reflector, to pass it over the tube of the argand, but this is of little consequence as the burner shades that part of it.

Fig. 19, is a section of the lanterns which were constructed for and used upon the Paisley and Johnston Canal, with hyperbolic reflectors, for the purpose of making the light diverge so as to illuminate the bridges and tracking path. This lamp, like the former, is also well adapted for steamers or coasting vessels, both being capable of showing a brilliant light ahead of the vessel, and could readily be turned or directed so as to illuminate powerfully any approaching object, without incommoding the eyesight of those on board, from the light being confined and only thrown directly forward. If a lamp of this kind be placed upon the front of each paddle-box near the top, and enclosed in a stout wooden box, with folding-doors, to be held open when the lamp was to be used, it would be of great service, especially in river navigation, as the light might be directed so as to illuminate both the banks of the river, and also the surface of the water for a long way a-head, and it might also be made to turn so as to light the water on the approach of the ferrymen, or to illuminate the landing-place of the passengers.

Fig. 20, is an elliptical lamp, sometimes used for illuminating the dials of public clocks, that are much exposed to violent gales of wind. The rays of light are well seen in hazy weather crossing in front of this lamp, in the opposite focus of the ellipse, and afterwards diverging until they cover the face of the dial.* This

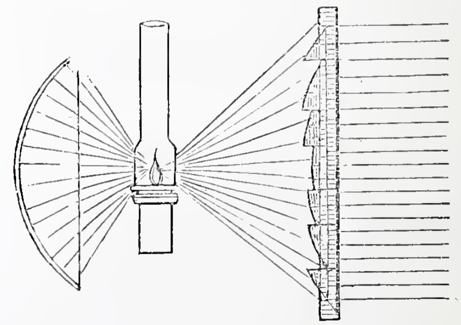
Fig. 20,



lamp would answer well at sea as it could be well protected, and transmit the light, even through an auger hole.

Fig. 21. is for the purpose of showing the application of the spherical reflector to increase the light upon the Fresnel lens; the reflected rays must cross each other in the flame, as I showed before,

Fig. 21.



fore, and therefore will pass through and enter the lens at the same angle as those issuing from the flame itself.

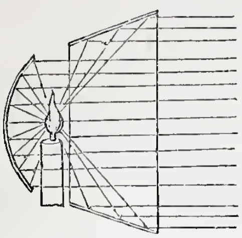
Fig. 22, is formed of a portion of two hyperbolas, and is frequently used both for carriage-lamps, and also on board steam vessels as signal lights. The conical silvered ring in front, it will be observed, reflects a portion of the rays issuing from the front of the flame, which otherwise would have been dissipated in space, and lost.

Fig. 23 shows the construction of convex reflectors, for the purpose of illuminating a wine vault, by intercepting the light that was formerly absorbed by the smoked and blackened arch and

* As the brilliancy of these lamps depends in a great measure upon a proper supply of air, the frame of the glass is made about half an inch wider than the front of the lamp, and is hinged so that it cannot touch the mouth, thus leaving a space clear for the admission of air of at least one quarter of an inch all round; see the figure.

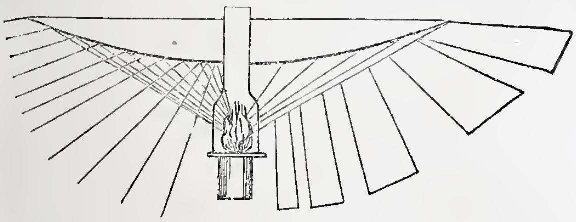
reflecting part of it in a horizontal direction upon the front of the catacombs. Before the application of those reflectors, the light was only good close by the burners, all the rest of the vault being in

Fig. 22.



comparative darkness; but as soon as they were applied, the light became diffused, and the whole of the bins or catacombs distinctly seen, even to the most distant corner. It will be unnecessary to

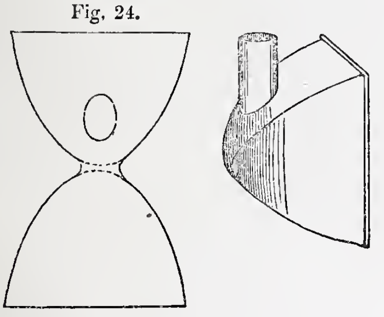
Fig. 23.



describe the method of forming this curve, as the lines shew it in the sketch.

Fig. 24, is for the purpose of showing how a reflector may be constructed from flat sheets, where the workman may not have proper tools to raise it with. After having formed the gage, apply it to the sheet, and cut out the top and bottom in one piece, as shown on the left of the figure; cut out the sides also, then bend the top and bottom until they fit the gage, which place between them, and tack them to it with a drop or two of solder, to hold them to the curve until you get the sides attached. This reflector is not so perfect as a raised one, but still it will be found to answer well if properly made.

Fig. 24.



To popular lecturers and teachers of youth, it will be obvious that by the means which we have been explaining, the nature of conic sections in regard to the reflection of light and sound, and also in the application of these curves to the construction of the Gregorian, Newtonian, and Cassegranian telescopes, and reflecting microscopes, may be explained to a mixed class, affording them a clearer and a more permanent idea of the proper curves for the reflectors of these instruments than by the usual method of diagrams alone. Thus, by directing their attention, in the first place, to the nature of each particular curve, by folding the strips of paper as in the former illustrations, this will give them an ocular demonstration that can be more easily recollected, than by referring to the diagrams or drawings of the instruments. It will at once become apparent what particular curve must be given to each reflector to form a perfect instrument. Thus in the Gregorian telescope we perceive that parallel rays from the object fall upon the great speculum; and as these must all be concentrated to one point, or meet in a focus, the polished surface of this reflector must be a parabola, as we find no other curve will reflect parallel rays to a point. Again, the rays, after crossing the focus, diverge and strike the small speculum, not as parallel rays, but as rays diverging from the focus; and as they must again be reflected as converging to another focus in the eyepiece, the curve of the same speculum must be a portion of an ellipse, whose conjugate foci is in the focus of the great speculum and the eyepiece, as no other curve than the ellipse will reflect the whole of the rays from one point to another. These points might even be demonstrated by means of a long piece of paper marked with parallel lines, and partly cut up into strips; these folded from the place of the one speculum to the other, and from it to the eyepiece, and the curves of each compared. If it is done on a large sheet of paper, so as to give the telescope a wide aperture, the difference of the curves will become quite apparent.

INORGANIC CHEMISTRY.

CHAPTER X.

CHEMICAL COMPOUNDS OF THE HIGHER ORDERS.—SALTS.

The substances we have hitherto enumerated are binary in their constitution, each consisting of two elements. These are denominated compounds of the *first order*. With their formation, however, the range of chemical affinity is by no means exhausted. These bodies are again capable of uniting among themselves to form compounds of a higher order and more complex structure, the greater part of which are called *salts*. The two binary substances that unite to form a salt, contain almost invariably a *common ingredient*. Thus sulphuric acid (an oxide of sulphur) unites with lime (an oxide of calcium), to form sulphate of lime: oxygen the common ingredient. Hydrosulphuric acid (a hydride of sulphur) unites with ammonia (a hydride of nitrogen), to form hydrosulphate of ammonia: hydrogen the common ingredient. Exceptions, indeed, are not wanting. Thus fluoboric acid (a compound of boron and fluorine) unites to form a salt with ammonia, which contains neither of these elements. It is likewise unusual for an element to enter into combination with a compound, yet examples are found in the oxychlorides and oxysulphurets. In general, therefore, we may say that chemical union takes place between bodies of a like rank or degree of complexity. The name 'salt,' as most of our readers well know, was originally limited to that useful culinary article, the chloride of sodium. Gradually it was converted from a specific to a generic term, being extended to all bodies which possessed analogous properties, just as the term *oil*, at first restricted to the produce of the olive berry, now embraces all animal and vegetable fats not congealing at common temperatures. Further, by a process not unfrequent under such circumstances, common salt, once the type of the class, is pronounced, by the majority of chemists, to be no salt at all. A salt, therefore, in the present acceptation of the word, is a body containing three or four distinct elements, and formed by the union of two binary compounds, which act relatively as acid and base. Both, in combining, lose, to a greater or less extent, their characteristic attributes, and become neutralized. Their flavour is no longer acid or alkaline, and they are without action upon vegetable colours. To this rule there are, however, many exceptions. Some acids are unable entirely to neutralize the more energetic bases. The arsenites, however much acid may be added, always exhibit an alkaline reaction. Nitrate of lead, although neutral in composition, reddens litmus. Again, bases may combine with more than one equivalent of an acid, and acids with more than one equivalent of a base. In such cases the respective properties of the acid, or of the base, are only in part held in abeyance.

At an early period of modern chemistry, all salts were supposed to contain oxygen. This view was greatly modified by successive researches, such as the discovery of the true nature of chlorine (previously considered to be an oxide), of the hydracids, and of the constitution of the sulphurets. These considerations led the great Berzelius to divide salts into the four following orders:—

I. Oxy-salts, compounds of oxygen acids with basic oxides. Example:—Sulphate of soda.

II. Hydro-salts, compounds of hydrogen acids with hydrogen bases. Example:—Hydrochlorate of ammonia, $H\,Cl + N\,H_3$.

III. Sulphur salts, compounds of sulphacids with basic sulphides. Example:—Sulpharseniate of potassium, $K\,S + As\,S^5$.

IV. Compounds of the halogens (chlorine, bromine, iodine, fluorine) with metals. Example:—Chloride of sodium, $Na\,Cl$.

Now, it will be at once perceived that the salts of the fourth order can have no analogy with those of the three preceding. They are, in fact, compounds of a lower rank, and as such have been already described. If we bestow the name of 'salt' upon chlorides and iodides, we cannot refuse it to oxides, sulphides, and hydrides, and with that the term loses all value. But, whilst rejecting this order, we shall have no difficulty in supplying the vacancy. These very haloid bodies, chlorides, fluorides, &c., display acid and basic properties, and unite together to form compounds, perfectly analogous to the salts of the three former orders. Our fourth order, therefore, will be:—

Haloid salts, compounds of acid with basic chlorides, &c. Example:—Hydrargo-chloride of potassium, $K\,Cl + Hg\,Cl$.

With this modification we shall adopt the arrangement of the great Swedish philosopher. Before, however, we enter upon a closer investigation of the different salts, it will be necessary to explain a doctrine which has received the sanction of names no less illustrious than those of Davy and Liebig—I mean the hydrogen theory of acids and salts. Oxygen is generally considered as the great acidifying principle; but, paradoxical as it may appear, its claims to this title may be disputed by hydrogen. Nearly all of the so-called oxygen acids, in their ordinary active state, contain hydrogen, which is ordinarily supposed to exist in the form of water. Thus, sulphuric acid is $S\,O^3\,H\,O$. It may indeed be obtained in the dry state, $S\,O^3$, but then it no longer acts as an acid. The new theory views both the hydracids and the oxacids (commonly so called) as true hydracids, with this only distinction, that, in the former, the radical of the acid may be either simple or compound; in the latter, it is always compound, and always contains oxygen. Thus, sulphuric acid, instead of being regarded as $S\,O^3 + H\,O$, is viewed as $SO^4 + H$. A salt is formed whenever the hydrogen of an acid is replaced by a metal, and thus the acids and salts are thrown into one series. Some acids (polybasic) contain more than one equivalent of hydrogen, and such invariably take up the same number of equivalents of a base in forming salts. When a salt is formed by the action of an acid upon a base, water is generally separated. This is, in all cases, accounted for by the new theory, on the supposition that the hydrogen of the acid unites with the oxygen of the base. $HCl + Ag\,O = Ag\,Cl + H\,O$; or, again, $S\,O^4\,H + Ag\,O = Ag\,S\,O^4 + H\,O$. But although this theory accounts for several phenomena with much plausibility, and is recommended by an appearance of simplicity, it is still beset with difficulties. Chromic and carbonic acids form glaring exceptions to the assumption, that anhydrous acids are unable to act as such. Again, the new theory obliges us to admit a legion of hypothetical compounds; such as, $S\,O^4$, $N\,O^6$. The silicates, the borates, the compounds formed by alumina and oxide of tin with alkalies, likewise elude the grasp of this theory, and would still have to be regarded as a class of oxysalts. These considerations determine us to regard the hydracids and oxyacids as two distinct classes of bodies, forming distinct series of salts.

GENERAL PROPERTIES OF SALTS.

Cohesion.—All salts are solid at ordinary temperatures, even although their constituents may be liquid or gaseous. Many, however, are volatile at elevated temperatures; and when in solution, they are volatilized along with the vapour of the solvent. The relation of colour between a salt and its constituents has not yet been determined. The majority appear to be colourless. A coloured base may often produce colourless salts, if the acid be colourless, but the salts of a coloured acid are always coloured. The acid salts of a base have frequently a deeper colour than such as are neutral, as among the chromates, vanadiates, &c. The same salt, in different modifications, may exhibit very different colours, as the sulphates of chromium. Sulphate of copper oxide is white, when anhydrous; but blue in its ordinary hydrated condition.

Soluble salts, for the most part, possess a strong, and often very unpleasant flavour. Their physiological action, when swallowed, is often intense. In this respect, a marked similarity has been discovered between such bodies as are members of the same isomorphous group. Runge lays down the law, that powerful flavour and strong physiological action, on the one hand, and intense colour and tinctorial power, on the other, are never coexistent. Amongst organic bodies, he appears to have made good his assertion, as the vegetable pigments, when pure, are tasteless and inert; whilst the organic alkalies, whose intense flavour and fearful virulence are well known, are invariably colourless. Even amongst inorganic matter, those bodies possessing the most intense colours are generally insoluble, and, of course, tasteless.

In *solubility*, salts differ greatly. Some, such as the sulphate of baryta, may, for all practical purposes, be deemed absolutely insoluble, as it requires 43,000 parts of water for solution. Others dissolve in their own weight of water, or even in a smaller proportion. The temperature of the solvent has a considerable influence. Most salts dissolve more plentifully in hot water than in cold, and a solution, saturated at 212° Fahr., on cooling, deposits a part of the substance dissolved, generally in a crystalline form. Other salts are equally soluble at all temperatures, and some bodies dissolve more freely in cold than in boiling water. Saline solutions boil at a higher temperature than pure water. A saturated solution of phosphate of soda boils at 223° Fahr.; that of saltpetre at 260°; acetate of potash, 337°. These solutions may therefore be used in heating bodies to a certain fixed temperature, an object often required, both in the laboratory and in manufactures. When salts are dissolved in water, they do not always, as might naturally be imagined, increase its bulk. On this subject, the following three laws have been proposed by Graham and Joule:—1st, Certain anhydrous substances, dissolved in water, occupy no space, the bulk of the solution being no greater than that of the water. 2nd, Other anhydrous salts, dissolved in water, assume a fixed and characteristic volume; so that the volume of the solution is not the same as that of the water contained therein, but greater or smaller in exact proportion to the atomic volume of the substance dissolved. 3d, When organic bodies dissolve in water, their carbon occupies no space; but their oxygen and hydrogen, if in the proper proportion to form water, occupy exactly the space of an equivalent weight of water.

Salts containing water, in whatever state, always increase the bulk of any portion of water to which they are added.

A portion of water, saturated, at any given temperature, with one salt, may still dissolve a certain quantity of a second, and even of a third, and may then still be able to take up an additional amount of the first. This arises either from chemical action ensuing between the different salts, or from the particles of the one being more minute than those of the other.

The *diffusibility* of salts, or the speed with which a saline solution will diffuse itself through a surrounding mass of tranquil water, has been recently investigated by Graham, and appears to vary greatly, according to the nature of the substance. Common salt travels through water with more than twice the speed of sulphate of magnesia. Isomorphous substances, dissolved in ten times their weight of water, are diffused at equal rates; and such pairs are equi-diffusive, not for chemically-equivalent quantities, but for equal weights. These considerations promise to throw a valuable light upon many unexplained phenomena, both in nature and the arts.

The solubility of salts in acid, alkaline, and saline solutions, has been but very insufficiently examined. Most salts, especially in the crystalline state, contain a considerable amount of water, which influences their geometrical form, and has long been known under the name, "water of crystallization." But we should be much mistaken in supposing the functions of water, in salts, limited to modifying their structure. Sometimes it plays the part of a base, sometimes of an acid; and, in other cases, it forms, what Graham calls, constitutional water. It may be asked—how are these distinctions observed? Crystalline water is recognised by its capability of expulsion by heat, the salt undergoing no further change than the loss of its regular form. The other three kinds cannot be driven off, except at temperatures sufficient to decompose the salt. Thus, common crystallized phosphate of soda contains 25 eq. of water. At a temperature of 212°, 24 eq. are expelled. The salt loses its crystalline form, but its chemical properties remain unchanged. On exposure to a red heat, the 25th eq. is also driven off, and then the salt is converted into pyrophosphate of soda, a substance presenting different reactions. Acid, basic, and constitutional water, may be known by the nature of the substances which are able to expel them, and take their place. Acid water can be replaced only by a stronger acid; basic water, by a more powerful base; constitutional water, by anhydrous salts. Thus, the water in a hydrated oxide, such as hydrate of potassa, $KO + HO$, can only be expelled by some acid, such as the sulphuric, which takes its place, and forms $KO + SO^3$. It is there to be considered as acid water. The 25th eq. of water in phosphate of soda is basic, since it may be replaced by another eq. of soda, forming $3NaO, PO^5, + 24\,aq.$ (Water of crystallization is generally denoted by the symbol aq.) The seventh equivalent of water in crystalline sulphate of zinc is constitutional, for it can be replaced neither by acids nor alkalies, but by anhydrous sulphate of potash, forming a double salt, $ZnO, SO^3\ (KO + SO^3) + O\,aq.$ That water can exert very powerful basic properties, has been proved by the researches of Reynoso. Thus, caustic potash converts quinine into quindine; at a temperature of 482° Fahr., water effects the same change. At 536°, it converts metaphosphates into ordinary tribasic phosphates, a transformation usually effected by heating them with an excess of potash or soda. At the same temperature, it appears capable of expelling many metallic oxides from their combinations with acids. According to Graham, the ordinary aqueous acids should be regarded as salts. Thus, $SO^3 + HO$, sulphate of water; $NO^5 + HO$, nitrate of water.

The principal laws of crystallization, and the doctrine of isomorphism, have been already explained. A few supplementary remarks may still be requisite. Crystalline, as well as organized substances, appear to have three axes, along which heat and vibrations are transmitted with different degrees of celerity. The cohesion of a body and its permeability to liquids are also influenced in a similar manner. Thus, in a piece of wood, all these influences are most easily transmitted in a direction parallel to the fibres, next in a line perpendicular to the fibres and to the annual layers of wood, and most slowly perpendicular to the fibres and parallel to the layers.

The optic axis in crystals, that is, the direction in which they do not refraet light doubly, is also parallel to the axis of symmetry. When exposed to magnetic influence, they take up such a position, that their optic axis points diamagnetieally (at right angles to the magnetic meridian). The analogy, so often recognized between crystals and organic bodies, is manifestly strengthened by these facts, as well as by the ensuing considerations.

Embryonic State of Crystals.—It has hitherto been maintained that crystals, from the very moment of their origin, exhibit precisely the same figure as when complete—that they undergo, in short, an increase in size, but no development. As regards the soluble salts, this view still holds good; but Brame has discovered that sulphur, iodine, phosphorus, camphor, and other bodies which may be crystallized, either by sublimation or by solution in gases and volatile oils, before assuming their known crystalline form, pass through a preliminary stage, which the author considers analogous to the *embryo state of plants and animals.*

Again, crystals undergo decay, and what may be termed their *skeletons* are, according to Hunt, frequently found in mines—the vacuities formed in them being sometimes filled up with foreign matter. Thus, decayed crystals of felspar are found filled up with oxide of tin. It is also conceived that the metamorphosis and metagenesis, or alternate generation, found amongst insects, are to a certain extent prefigured in chemical changes. Upon these profound considerations we cannot, however, at present enter. Let it suffice to say that crystals, even if not considered as strictly analogous to plants and animals, must be admitted to display the earliest signs of individuation. A crystal, like an organic being, is an individual, and must cease to exist, as such, before it can be made the subject of chemical transformation.

We read that salts are deprived of their crystalline water on exposure to the blue ray of light. With oxalate of ammonia, prussiate of potash, and sulphate of copper oxide, the writer was unable, in a prolonged series of experiments, to recognize any such result.

Decompositions.—Generally speaking, salts are decomposed with greater facility than the binary substances by which they are formed. Some few salts, such as the carbonate and pyrophosphate of silver oxide, are decomposed by the direct *light* of the sun, and especially by the blue ray. *Heat* is a more frequent cause of decomposition. At elevated temperatures, volatile acids, and such as may be resolved into volatile constituents, are driven off, except when combined with the more energetic bases, such as potash and soda. On this subject Persoz proposes the following law:—"All salts obtained from an acid and oxide, *both formed directly* (phosphoric acid is formed directly, sulphuric indirectly), will resist the action of an elevated temperature without decomposition. But, also, an acid formed indirectly by the union of a *compound radical* with oxygen, may give rise to stable salts in combination with potassa, soda, lithia, baryta, strontia, lime, and perhaps a few other bases, provided that the compound radical is produced by the *direct union* of a simple radical with oxygen. An acid formed directly, but which naturally exists in the gaseous state, yields unstable salts, by reason of its elasticity."

Current electricity decomposes probably all salts which can be rendered conductors, either by solution or fusion.

Salts, like compounds of the first order, are decomposed, if placed in contact with any substance whose affinity for one of their constituents is greater than that of the other constituent. The mutual action of salts, when two or more are present in solution together, is also a very frequent source of decomposition. Here the results of affinity are modified by cohesion, elasticity, and diffusibility, those compounds being formed by preference, whose cohesion enables them to subside as insoluble precipitates, whose elasticity causes them to escape as vapour, or whose diffusibility makes them pervade most rapidly a large volume of water. It is impossible, therefore, to foretell what will be the result of a saline mixture, unless we are acquainted with all the circumstances—the temperature, the respective proportions, the amount of water present, &c.

ORDER I.—OXYSALTS.

All the salts of this class are composed of oxyacids, in combination with basic oxides. The oxysalts of ammonia are no exception, since in them the base, NH^3, always exists along with an equivalent of water, and may, therefore, as the phenomena of isomorphism render highly probable, be viewed as NH^4O, the oxide of the hypothetical *quasi-metal,* to which we have already alluded. The salts are generally arranged according to their respective acids.

SULPHATES.

Formed by the action of sulphuric acid upon the metals, their oxides or carbonates. Six of them may be considered insoluble—the sulphates of baryta, and of the oxides of tin, antimony, bismuth, lead, and mercury. Those of strontia, lime, zirconia, yttria, and silver oxide, are scantily soluble; the rest soluble. All, except those of potash, soda, lithia, baryta, strontia, and lime, are decomposed at a white heat, the acid escaping in part unchanged, and in part resolved into a

mixture of sulphurous acid and oxygen. If ignited with carbon, they are decomposed, and a metallic sulphide remains.

Sulphate of potash, K O, S O. Formed by neutralizing carbonate of potash with sulphuric acid. Anhydrous, bitter, fusible—soluble in 16 parts of water. *Bisulphate*, $K\ O + 2\ SO^3$, generally found in crystals with 1 eq. of water. Formed by exposing the former with half its weight of strong sulphuric acid to a heat just below redness. Reddens litmus; decomposed by heat; soluble in two parts of water.

Sulphate of soda (Glauber salts), $Na\ O + S\ O^3$. Formed by treating common salt with dilute sulphuric acid. Crystallizes with 10 eq. of water. More soluble at 91° than at 212°.

Sulphate of ammonium oxide (ammonia), $N\ H^4\ O,\ S\ O^3$. Crystallizes with 1 eq. of water.

Sulphate of baryta, $Ba\ O + S\ O^3$. Insoluble in water and all acids, except hot sulphuric, from which it is again precipitated by water.

Sulphate of lime, $Ca\ O + S\ O^3$. Dissolves in 500 parts of cold water. Soluble in nitric acid.

Sulphate of magnesia, $Mg\ O + S\ O^3$ (Epsom salts). Crystallizes with 1 eq. of water. Formed on the large scale, by treating magnesian limestone with dilute sulphuric acid. Nauseous, efflorescent; soluble in its own weight of water.

Sulphate of alumina, $Al^2\ O^3 + S\ O^3$. Formed by saturating dilute sulphuric acid with hydrated alumina, and evaporating. It has an acid reaction.

Sulphate of oxide of manganese, $Mn\ O,\ S\ O^3$. Rose-colour, transparent, soluble. Not decomposed at a red heat.

Sulphate of protoxide of iron (green vitriol), $Fe\ O, S\ O^3, H\ O$. Formed by exposing sulphides of iron to moist air. Soluble, of inky taste. Gives off all its acid at a red heat, with little loss. White, if perfectly pure; the green tint owing to a trace of sesquioxide. Used in dyeing, the manufacture of ink, and of fuming sulphuric acid. Its solution, exposed to the air, is converted into disulphate of sesquioxide, $2\ Fe^2\ O^3 + SO^3$.

Sulphate of sesquioxide, $Fe^2\ O^3 + S\ O^3$. Obtained by treating the former with a mixture of sulphuric and nitric acids. White forms a brown solution; loses all its acid at a red heat.

Sulphate of zinc oxide, $Zn\ O,\ S\ O^3$ (white vitriol). Very soluble; has an acid reaction, though neutral in composition.

Sulphate of copper oxide, $Cu\ O,\ S\ O^3$ (blue vitriol). Prepared by roasting the native sulphide, or dissolving the metal in hot sulphuric acid. Crystallizes with 1 equiv. of water. White, when anhydrous.

Sulphate of mercuric oxide, $Hg\ O,\ 2S\ O^3$. Formed by dissolving mercury in strong sulphuric acid at a moderate heat, and evaporating to dryness. Decomposed by hot water, leaving a yellowish subsalt (turpeth mineral), $4\ HgO + 3\ SO^3$.

Sulphate of silver oxide, $Ag\ O,\ S\ O^3$. Formed by boiling granulated silver in strong sulphuric acid. Sparingly soluble.

Sulphates of chromic oxide. Sulphuric acid and sesquioxide of chromium form various combinations, not only by uniting in distinct proportions, but also by undergoing certain modifications not yet understood. Berzelius, in fact, suggests that the two allotropic modifications of metallic chromium, which he respectively designates Cr, a, and Cr, b, may be traced throughout all its compounds, forming two distinct series. To prevent all misapprehensions, we here cite Dr. Daubeny's luminous statement of the difference between isomerism, allotropy, and dimorphism:—

"By *isomeric*, we mean bodies composed of the same elements in the same proportions, but exhibiting perfectly distinct properties, and not liable to pass into each other. In this case, then, we conceive that the bodies respectively produced in the manner supposed, may present, according to the mode of grouping or aggregation of their particles, such entirely different characters, as entitle them to be regarded as chemically distinct, and nowise related to each other.

"By *allotropic*, we mean those in which a different arrangement of particles has produced some modification of the properties of a body, but not an assumption of new and distinct ones, and in which the bodies are easily made to pass from one condition to the other.

"By *dimorphous*, we mean bodies susceptible merely of such a mechanical change as is productive of a distinct mode of crystallization, a difference in hardness, colour, &c., but which leaves the chemical properties unaffected."

SULPHITES.

The salts of sulphurous acid are, generally speaking, of little importance. Except those of the alkalies, they are, for the most part, of sparing solubility. More powerful acids decompose the sulphites with effervescence, but nitric acid converts them into sulphates. If strongly heated, or even in the cold when in solution, they absorb oxygen, and are converted into sulphates.

NITRATES.

Nitrates may be prepared by the action of nitric acid upon metals, their oxides, or carbonates. With the exception of a few subsalts, all are soluble. All are decomposed at a high temperature, the acid either passing off unchanged, or decomposed into a mixture of the lower oxides of nitrogen.

Nitrate of potash (nitre, saltpetre), $K\ O + N\ O^5$. Prepared by the slow oxidation of animal refuse, mixed with calcareous earth. It is then dissolved out with water, and freed from other salts by recrystallization. Colourless, crystallizes in six-sided prisms; very soluble. Used in the manufacture of gunpowder, and in that of nitric acid, in which, however, it has been, to a great extent, superseded by the following:—

Nitrate of soda, $Na\ O + N\ O^5$. Found native, especially at Atacama. Very similar to the preceding; deliquescent; cannot be used for making gunpowder.

Nitrate of ammonia, $N\ H^4\ O + N\ O^5$. Deliquescent. At 400° — 500° Fahr. it is entirely resolved into water and protoxide of nitrogen.

Nitrate of baryta, $Ba\ O + N\ O^5$. Crystalline, soluble in 12 parts of water.

The nitrates of lime and magnesia, $Ca\ O,\ N\ O^5$, and $Mg\ O,\ N\ O^5$, are both very deliquescent, and soluble in alcohol.

Nitrate of copper oxide, $Cu\ O,\ N\ O^5$. Deep blue, very soluble and deliquescent. Decomposed at 400° Fahr. into a green insoluble subsalt.

Nitrate of lead oxide, $Pb\ O,\ N\ O^5$. Litharge is digested in dilute nitric acid. Forms opaque crystals.

The compounds of nitric acid with the oxides of mercury are numerous. Nitrate of suboxide (mercurous nitrate) is prepared by digesting an excess of mercury in dilute acid. If mercury is boiled in strong nitric acid, we obtain nitrate of protoxide (mercuric nitrate), $Hg\ O,\ N\ O^5$, which is decomposed by hot water, yielding a yellow subsalt.

Nitrate of silver, $Ag\ O,\ N\ O^5$, is formed by dissolving silver in the dilute acid. Decomposed at 600° — 700° Fahr., leaving pure metallic silver. Used by surgeons as a cautery, and forms the basis of marking inks.

HYPONITRITES (NITRITES).

Little known. Generally formed by heating the respective nitrates to a temperature insufficient for their total decomposition. On the addition of strong sulphuric acid, they give off deep red fumes. They are mostly yellow, crystalline, soluble, neutral to vegetable colours. Detonate when heated with combustibles.

CHLORATES.

The chlorates much resemble the nitrates. They are decomposed at a red heat, evolving pure oxygen gas, and leaving a metallic chloride as residue. They explode violently if struck or rubbed with carbon, sulphur, or phosphorus. Many are deliquescent, all soluble, that of potash least freely.

Chlorate of potash, $K\ O,\ Cl\ O^5$, is produced by passing a current of chlorine gas through a vessel containing sulphate of soda, into one filled with chloride of potassium in solution.

HYPOCHLORITES.

These salts are produced by allowing chlorine gas to act upon salifiable bases. The most important is the hypochlorite (commonly called chloride) of lime, much used as a bleaching powder. When the aqueous solution is exposed to the atmosphere, chlorine gas is evolved. The hypochlorite of soda is

now frequently employed for the same purposes. The hypochlorites are regarded by Millon as oxychlorides: Ca O, Cl O = Ca O $\left\{ \begin{matrix} Cl \\ O \end{matrix} \right.$.

PHOSPHATES.

The three modifications of phosphoric acid produce three corresponding series of salts, the ordinary phosphates, pyrophosphates, and metaphosphates. If these salts are neutral in composition, 1 eq. of a base combines with 1 of acid, $MO + PO^5$; if 2 eq. of a base are united with 1 of acid, we have a *disalt*, $2MO + PO^5$; and if 3 eq. of base combine with 1 of acid, it is a *trisalt*, $3MO + PO^5$. Water plays here the part of an alkaline base towards all the three modifications of acids, either alone, or along with some metallic oxide. All protophosphates of neutral composition are soluble, and redden litmus. The triphosphates, except those of the alkalies, are sparingly soluble in water, but dissolve in dilute nitric or phosphoric acid. The triphosphates bear a red heat unchanged, but the phosphates and diphosphates are converted into pyrophosphates and metaphosphates.

Triphosphate of soda, $3NaO + PO^5$, generally crystallizes with 24 eq. of water. The salt called ordinary, or *rhombic phosphate*, is $2NaO, HO + PO^5$. It also crystallizes with 24 eq. of water, and is prepared by neutralizing with carbonate of soda the acid phosphate of lime, prepared by treating calcined bones with sulphuric acid. Both these salts yield a *yellow* precipitate with soluble salts of silver.

Acid triphosphate of soda (commonly called biphosphate), $NaO, 2HO + PO^5$.

Microcosmic salt, or triphosphate of soda with ammonia and basic water, $NaO, NH^4O, HO + PO^5$, is formed by mixing 1 eq. of hydrochlorate of ammonia with 2 of rhombic phosphate of soda. At a red heat it loses ammonia and water, and is converted into metaphosphate of soda. It is much employed in blowpipe analysis.

Bone earth is a phosphate of lime, formed by calcining bones, $8CaO + PO^5$.

Triphosphate of silver oxide, $3AgO + PO^5$. A yellow powder, very soluble in nitric acid and ammonia.

Pyrophosphate of soda, $2NaO + PO^5$, is prepared by heating rhombic phosphate, so as to expel its basic water. *Pyrophosphate of silver oxide*, $2AgO + PO^5$, is a snow-white powder.

Metaphosphate of soda, $NaO + PO^5$, is formed by heating the pyrophosphate to low redness. A deliquescent, vitreous body, which does not crystallize.

In the ordinary phosphates, therefore, an equivalent of acid is combined with three equivalents of base (either a metallic oxide or water), in the pyrophosphates with two, and in the metaphosphates with one only.

ARSENIATES.

The salts of arsenic acid closely resemble the phosphates, but have not been obtained under similar modifications. Those containing two equiv. of basic water are soluble, the rest are of sparing solubility. Many bear a red heat without decomposition, but all are decomposed if ignited with charcoal.

The arseniate of potash may be formed by igniting saltpetre with an equal weight of arsenious acid.

ARSENITES.

The salts of arsenious acid are less stable than the arseniates. Those of the alkalies are soluble, amorphous, and may be prepared by adding arsenious acid to a hot solution of the alkali. The rest are nearly insoluble, but dissolve readily in free arsenious acid and nitric acid. All are decomposed on ignition.

CHROMATES.

The chromates are usually analogous to the sulphates, but are either of a yellow or red colour. The alkaline chromates resist a very high temperature, but those of the heavy metals are decomposed at a red heat.

Chromate of potash, $KO + CrO^3$, is prepared by neutralizing the following salt with carbonate of potash. Lemon-yellow; very soluble. Bichromate of potash, $KO + 2CrO^3$, is made by igniting a powdered mixture of chrome-iron and chalk, constantly stirring. The mass is then extracted with hot water, acidulated with sulphuric acid, the iron removed by the addition of chalk, and from the solution of bichromate of lime thus obtained, the remaining bichromates are obtained by double decomposition. A deep orange-red salt, very soluble, highly poisonous; ulcerates the skin. Much used in dyeing. The chromates of the alkaline earths and heavy metals are insoluble. Those of baryta, zinc, and lead are yellow; that of mercury orange; and that of silver deep red. A fine red dichromate of lead oxide, $2PbO + CrO^3$, much used as a paint, is obtained by fusing nitre at a low red heat, and adding chromate of lead oxide by degrees, until the nitre is almost spent. The soluble matter is then removed by water.

BORATES.

Boracic acid is feeble, and neutralizes alkalies imperfectly. The borates are very fusible, but are not easily decomposed by heat. Except those of the alkalies, they are of sparing solubility. The borate of soda, the most important of these salts, has been described elsewhere.

CARBONATES.

The salts of carbonic acid, except those of potash, soda, and lithia, are all decomposed by heat, and sparingly soluble in water. All are decomposed by the more powerful acids.

Carbonate of potash, $KO + CO^2$, is obtained in an impure state by burning timber to ashes, and lixiviating the residue with water. In this state it is contaminated with sulphate of potash and chloride of potassium. When these bodies are partially removed by recrystallization, it is called *pearl-ash*. To obtain it in a state of purity, however, another source is needed. This is *crude tartar* (bitartrate of potash), a mass separated from the juice of the grape during fermentation. By igniting and lixiviating this, we obtain a moderately pure carbonate of potash, commonly called *salts of tartar*. Very soluble, deliquescent, of an alkaline taste, and reaction.

Bicarbonate, $KO + 2CO^2$, which is much less soluble, is made by transmitting a current of carbonate acid gas through a solution of the above. At a red heat, it is reduced to carbonate.

Carbonate of soda, $NaO + CO^2$, is now obtained by decomposing common salt with sulphuric acid, and roasting the sulphate obtained in a reverberatory furnace along with an equal weight of limestone, and half the amount of powdered coke or charcoal. It may also be obtained from the ashes of sea-plants (kelp, barilla). Very similar to carbonate of potash in its properties, but less soluble, and not deliquescent. Used in the manufactures of glass and soap; sold to laundresses under various fanciful names in a grossly adulterated state. The bicarbonate, used in preparing effervescing draughts, is very similar to the bicarbonate of potash.

Sesqicarbonate of ammonia, $2NH^4O + 3CO$. Prepared by subliming one part of sal-ammoniac with one and a half parts of carbonate of lime. Volatile, hard, translucent; it is converted into bicarbonate if exposed to the air. The carbonates of baryta, strontia, lime, and magnesia occur naturally, and have been described in p. 425.

Carbonate of protoxide of iron, $FeO + CO^2$, occurs in the earth, and in chalybeate springs. When prepared artificially, it readily undergoes decomposition.

Dicarbonate of copper oxide, $2CuO, CO^2 + HO$, occurs naturally, as the beautiful ore *malachite*. When formed by the action of moist air upon copper, it is called *verdigris*. Obtained as a green powder (*mineral green*) on precipitating blue vitriol with carbonate of soda, boiling, and washing with hot water. *Blue verditer* is $3CuO + 2CO^2 + HO$.

Carbonate of lead oxide, $PbO + CO^2$ (white-lead, ceruse), is obtained by exposing thin sheets of lead to the vapour of vinegar. A white pulverulent precipitate.

HYDRATES.

When metallic oxides are precipitated from their solutions by means of a stronger base, or when they are formed by the action of moist air upon the metal, they are almost invariably in combination with an eq. of water, which may be regarded as

an acid. The hydrates differ little in properties from the corresponding oxides. They are, however, more soluble, and sometimes vary in colour. Thus, oxide of copper is black, but its hydrate, $Cu\ O + H\ O$, is deep blue.

DOUBLE SALTS.

With the formation of the ordinary salts, the range of chemical affinity is by no means exhausted. Many of the salts above described are capable of entering into mutual union, and of forming so-called double salts. Here also, as in the single salts, we usually find an ingredient in common; for the most part the acid. The two bases never belong to one and the same isomorphous family. Sulphuric acid has an especial tendency to form double salts, the most interesting of which are the family of *alums.* Common alum, the model of this group, is a double sulphate of alumina and potash, $K\ O,\ S\ O^3 + Al^2\ O^3,\ 3\ SO^3$. It generally crystallizes with twenty-four eq. of water, which is easily expelled by heat. Alum is obtained on the large scale for manufacturing purposes, by roasting aluminiferous shales, lixiviating the residue, and allowing the solution to crystallize. It is often contaminated with iron, which greatly lowers its value. This impurity may be removed by dissolving the alum in three times its weight of boiling water, pouring the liquid into a wooden vat, and stirring incessantly until it is quite cold. The liquid is then poured off, and the *alum meal* allowed to drain upon some porous substance.

Alum affords us an excellent example of the important phenomenon of *substitution.* Its equivalent of potash may be replaced by soda, oxide of ammonium, protoxide of iron, protoxide of manganese, magnesia, and probably also by lime, and the oxides of zinc, copper, cobalt, and nickel. In like manner, the alumina may be replaced by the sesquioxides of iron, chromium, and manganese. Thus an extensive series of compounds is obtained, closely resembling common alum in form, constitution, taste, and in a majority of instances in colour. Double carbonates are likewise of frequent occurrence.

ORDER II.—HYDROSALTS.

In the salts of this order, both acid and base contain hydrogen. Inorganic chemistry furnishes only two bases of this nature—ammonia, and phosphuretted hydrogen. These combine directly with the hydracids. Ammonia, besides, unites to form salts with bisulphuret of carbon, and fluoride of boron.

Hydrochlorate of ammonia, $N\ H^3 + H\ Cl$ (sal-ammoniac); formed by decomposing sulphate of ammonia with chloride of sodium. A tough, soluble, volatile solid. The hydriodate and hydrobromate are similar in their constitution.

Hydrosulphate of ammonia, $N\ H^3 + H\ S$; formed by subliming a mixture of one part of sulphur, two of sal-ammoniac, and two of unslaked lime. For use as a test liquid, it is prepared by saturating dilute caustic ammonia with sulphuretted hydrogen gas. It is obtained in large quantities in the manufacture of coal gas, and is one of the principal sources whence the ammoniacal compounds are obtained.

The salts of phosphuretted hydrogen are less known. They exist only in the anhydrous state, and are all decomposed by water.

ORDER III.—SULPHUR SALTS.

We have already pointed out the close analogy existing between the oxysalts, and those compounds in which two sulphides play the parts of base and acid. The principal sulphur bases, are the protosulphides of potassium, sodium, lithium, barium, strontium, calcium, magnesium, and hydrosulphate of ammonia. The sulphur acids, are the sulphides of arsenic, antimony, tungsten, molybdenum, tellurium, tin, gold, sulphuretted hydrogen, bisulphide of carbon, and sulphide of selenium. Hydrosulphuric and hydrosulphocyanic acids act indifferently, either as hydracids, or as acid sulphides. These salts may be arranged in families according to their acid, but are not sufficiently important to require special description.

ORDER IV.—HALOID SALTS.

These are formed by the union of two binary compounds, one or both of which are analogous to common salt. The principal groups are double chlorides, double iodides, and double fluorides. The chlorides, iodides, &c. of potassium, sodium, lithium, &c. act as bases; those of mercury, gold, platinum, palladium, rhodium, iridium, and osmium as acids.

OXYCHLORIDES.

A numerous class of bodies have been discovered, consisting of a chloride in combination with an iodide.

Oxychloride of copper, $Co^4 \left\{ \begin{matrix} O^3 \\ Cl \end{matrix} \right\}$ is used in painting, under the name *Brunswick green.* It is prepared by treating metallic copper with hydrochloric acid. There are several *oxychlorides of lead,* $Pb^8 \left\{ \begin{matrix} O^7 \\ Cl \end{matrix} \right\}$ (*Cassel, or patent yellow*), is prepared by fusing one part of sal-ammoniac with ten parts of red lead. *Oxychloride of antimony* falls as a white powder, when sesquichloride of antimony is put into water.

Millon considers the oxychlorides not as compounds of an oxide with a chloride, but as metallic peroxides, in which a certain amount of oxygen has been replaced by chlorine.

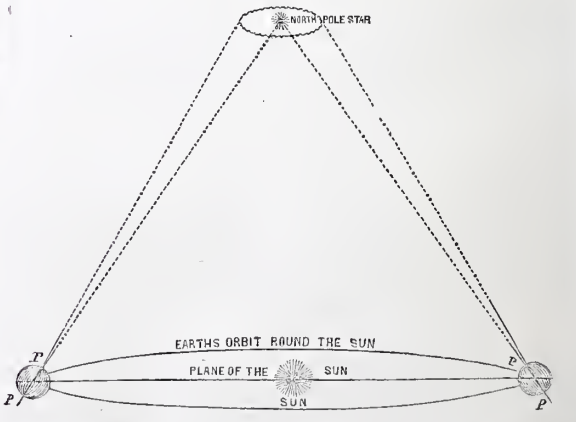
ASTRONOMY.

CHAPTER VII.

UNIVERSAL GRAVITATION APPLIED TO THE EXPLANATION OF THE MECHANISM OF THE HEAVENS.

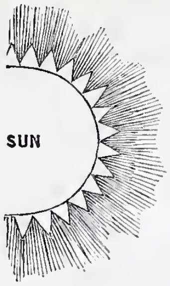
NOT only has the earth two motions, as we have seen—one round its own axis, another round the sun—but its orbit also, which to aid the imagination we may conceive to be a material oval ring, has three distinct motions:—one, in constantly passing from the oval to the circular, and again from the circular to the oval form; another, in vibrating upwards and downwards like a balance, at one time converging to, at another time diverging from, the plane of the sun; and a third, in continually revolving round the sun, in the direction of the earth's motion. But the earth itself has a third motion which has not as yet been alluded to, except in reference to one of its effects, the *precession of the equinoxes.* It was discovered by Hipparchus of Alexandria, so long ago as 140 years before the Christian era, that the sun's place in the heavens at the equinox was not a fixed point; that a star, which had marked this spot a century before, was now considerably eastward; in short, that the equinoctial points were gradually, although slowly, moving westward,—and to this phenomenon was given the name of the *precession of the equinoxes.* Neither Hipparchus, nor any astronomer after him till the days of Newton, had the most remote idea of the cause of

Fig. 22.



this phenomenon; but it is now well known to arise from the joint action of the sun and moon, but particularly the moon, upon the protuberant matter around the earth's equator. Had

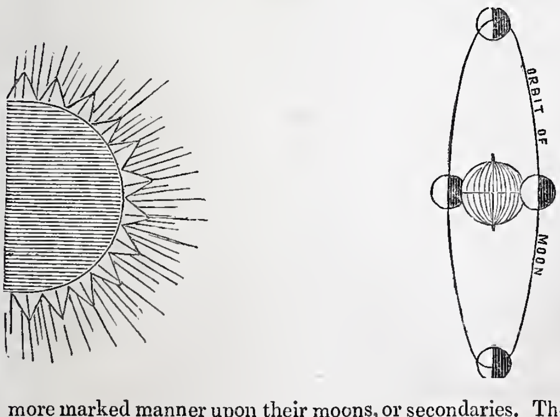
the earth been a perfect sphere no such motion would have occurred, but the earth is flattened at the poles, and bulges out somewhat towards the equator, and this peculiar form gives rise to an unequal attraction on the different parts of the earth's surface by the sun and moon, which on this account pull or draw this bulging protuberance slightly to one side. The earth's axis is inclined by a certain amount to the plane of the sun, but any force which would act more on one side of the earth than another would, of course, change the position of the axis. The sun and moon do act more on one side than another of the earth, and pull it off the balance, as it were; causing its axis to perform a circular revolution around a fixed point in the heavens; as shown by the different positions of the earth in the preceding figure.—See fig. 22.



This motion of the earth may be illustrated by a top spinning upon the end of a rod held vertically; if the rod is held firmly in the hand, and the upper end made to go round a small circle, the top will now take two motions: it will continue spinning rapidly round on its axis as before, and the axis itself will assume a circular motion. And if the person holding the rod walk round a circle, the top will represent all the three motions of the earth:—a circular motion round the sun, shifting its position in space; a motion round its own axis; and this axis itself a gyratory motion around a fixed point in the heavens. A close consideration of this subject will show that the necessary consequence of such a motion will be a change in the position of the north pole of the heavens, and a constant falling back or retrogradation of the equinoctial points. The apparent course of the sun in the ecliptic is from west to east, and if anything occur in the motion of the earth to cause the position of its axis to vary in reference to the plane of the sun, the equinoctial points will shift their places in the heavens. In this case they do so at a very slow rate, requiring 26000 years to move round the whole heavens; the north pole, of course, requiring the same time to complete a circle round a fixed point.

The effect of gravitation, as shown in the mutual attractions of the planets upon one another, and of the sun upon the planets, causing those disturbances to which we have called attention under the name of *perturbations*, is not confined to the primary planets, but acts in a much

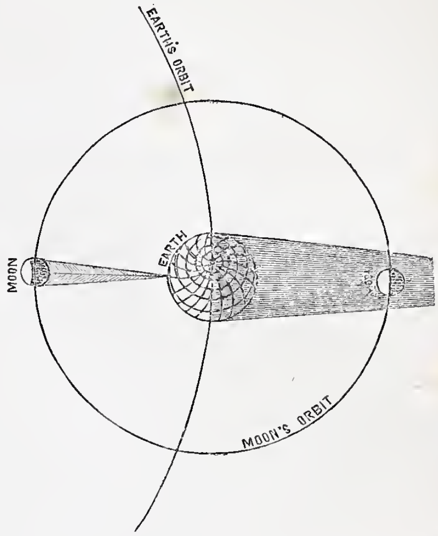
Fig. 23.



more marked manner upon their moons, or secondaries. These bodies are not only under the influence of the attractive power of the sun, which is sufficient to carry them round that luminary in company with their primaries, but they are also subject to the attraction of these primaries, which makes them circulate around them also, while they are at the same time partaking of the common motion around the sun. Now, if a moon revolved around a planet in such a manner that its distance from the sun would always be the same, as in fig. 23, its motion would vary but to a very small extent.

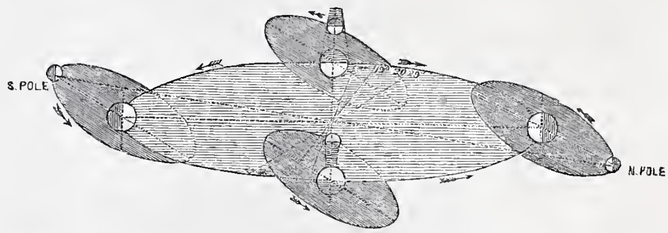
If, again, its orbit were circular, and in the same plane with

Fig. 24.



the orbit of its primary, as shown in fig. 24, the variations of this moon would be but slight. It is obvious that its

Fig. 25.



shadow would eclipse part of its primary in every revolution around it, and the same thing also would happen to it from the shadow of its primary—part of the planet being eclipsed when its moon passed between it and the sun, and the moon being eclipsed when the planet passed between it and the sun.

It so happens, however, that neither of these is the case of nature; the satellites are not always at the same distance from the sun as their primary planets; their orbits are not circular, but elliptic, and much more so than those of their primaries; and the planes of their orbits are all somewhat, but few of them very much, inclined to the planes of their primaries. Fig. 25 is a representation of the manner in which the moon revolves round the earth. The plane of her orbit is inclined about 5 degrees to that of the earth's orbit, which in its turn is about 23 degrees inclined to the plane of the sun.

The irregularities of the moon's motion may be given as a good example of the effect of gravitation in disturbing the motions of the satellites, but these irregularities are so numerous that we can here only allude to a few. It will show the complexity of the subject, however, to mention that the moon is subject to about *fifty* different irregularities from the effects of the mutual gravitation of the sun, earth, and planets

upon her motions; about twenty of these are too minute to be distinguished by observation, although well konwn, from mathematical calculation, to exist. Nearly thirty irregularities, however, must not only be observed but be taken into account by the astronomer, before he can predict the moon's exact place in the heavens, so as, with the utmost accuracy, to foretell eclipses, &c., for ages to come. By an attentive and careful consideration of the last figure, showing the moon's orbit round the earth in connection with the law of gravitation, it cannot fail to be seen, that when the moon is in that part of her orbit between the earth and the sun, in so far as she is nearer the sun than the earth, she is so much the more attracted; so that, if both earth and moon were suddenly arrested in their onward path, and allowed to fall freely to the sun, the moon, being nearer and under a greater attractive power at the outset, would fall towards the sun much faster than the earth. If the moon were in that part of her orbit which is at the greatest distance from the sun, so that the earth in this case would be between the moon and the sun, and consequently more under the influence of his attraction than the moon, matters would now be reversed; and were the earth and moon to be allowed now to fall freely to the sun, the earth would fall much faster than the moon. Hence it is obvious, that when the moon is nearest the sun in her orbit, the tendency of the sun's increased attraction is to draw the moon away from the earth, and make her circulate round him in that position, so that the moon's orbit is in this manner elongated. When, on the other hand, the earth is nearest the sun, the tendency of his attraction is now to draw it away from the moon, and to cause both bodies to circulate round him in this manner, the moon's revolution round the earth being put a stop to; in this case, also, the moon's orbit is elongated, and her motion rendered slower. Having now seen the effect of the sun's attraction upon the moon's motion when she is in syzygies, or when she is in a straight line with the earth and sun, let us see what effect it would produce when she is in quadrature, or in those parts of her orbit, either before or behind the earth, when she is crossing the earth's orbit, which positions are at an equal distance from the sun with the earth. If both bodies were allowed to fall to the sun in this position, it is evident, from the direction in which his attractive power operates, that they would be drawn closer and closer together, and that they would meet before they fell to his surface; we therefore see that the effect of the sun's attraction upon the moon in either of these positions is to draw her nearer the earth, to enable the earth's attraction to have more power over her, and consequently to quicken her motion.

Had the sun's attraction upon the moon been always of equal strength, and exerted in the same direction, as upon the earth, the moon's motion would not have been subject to this irregularity; but the strength of the sun's attraction upon the moon in her orbit round the earth is ever varying, the direction of this attraction is never the same as that exerted upon the earth, unless when the sun, earth, and moon, are in a straight line; and for these reasons the moon's orbit round the earth is constantly changing—its axis revolves round the earth, carrying along with it the perigee, or point of the orbit nearest the earth, and the apogee, or the point farthest distant from the earth. The moon's orbit revolves round the earth in this manner in the period of about nine years. Sir Isaac Newton saw this revolution of the moon's orbit as a necessary consequence of universal gravitation; but in the attempt to solve this problem mathematically, he was surprised to find that, according to theory, it ought to require eighteen years to accomplish one revolution, whereas, it actually required only about half this time. He exerted his utmost efforts in vain, in the endeavour to reconcile the existing rate of motion at which the moon's orbit moved, to his theory of gravitation; and he left to future astronomers a legacy to test their mathematical skill and genius, by solving a problem which had baffled the transcendent abilities of the great Englishman. After many failures by the first mathematicians and astronomers of the age, and after gravitation was quite given up as unable to account for this rate of motion in the moon's orbit, Clairaut, a Frenchman of distinguished talent and celebrity, at length discovered the clue to the solution of the problem, and triumphantly proved the universality of the great law of gravitation.

If the moon's orbit had no other motion than a simple revolution in a plane at a certain inclination to the plane of the earth's orbit, and if the points at which the moon's orbit intersects or crosses the plane of the earth's orbit were fixed in the heavens, it is evident that no eclipses could take place, unless when the sun and moon happened to pass these points at the same time, which would be a very rare occurrence. It was observed, however, from a very remote period of antiquity, that the point at which the moon crosses the ecliptic, or sun's apparent path in the heavens, was not fixed; that if a certain star pointed out the spot of this intersection during one revolution of the moon, the same star would fail to mark the point of crossing during succeeding revolutions; and that, in short, this point of crossing, which was called the moon's *node*, gradually moved westward upon the ecliptic, leaving the fixed star farther and farther behind during every new revolution, till after a certain number of years the said point of crossing, or node, crept round the whole ecliptic, and again reached the spot which the fixed star originally served to indicate. This motion of the moon's orbit was denominated the *retrogradation of the moon's nodes.* Imagine an oval wheel with a long axle, fixed by spokes to the rim, and placed nearer one end than the other; put the axle perpendicularly into water, so that the rim of the wheel may be on the surface of the water all round. Draw the axle a little off the perpendicular to one side, and one portion of the rim will be under water, and another portion above it. The surface of the water in this illustration will represent the plane of the earth's orbit; the wheel, the moon's orbit; the part of the rim nearest the axle will represent the moon's perigee; the part farthest from the axle, the moon's apogee; and the two points in the rim, where it comes in contact with the water, will be the moon's nodes; while the axle itself, at the point where the spokes meet, will represent the position of the earth. Make this wheel revolve round the axis from right to left, and we have a representation of the revolution of the moon's orbit, which is accomplished in about nine years—denominated the revolution of the *apsides*, or of the straight line joining the apogee and perigee. At the same time, make the upper end of the axle revolve in a small circle, around a point perpendicular to the position of the earth; move the axle in this circle in a contrary direction to the motion of the rim, or from left to right; this revolution of the axle will cause different portions of the rim to be submerged in the water, and the nodes to move round the whole rim from left to right, during each revolution of the upper end of the axle: this will represent the retrograde revolution of the moon's nodes, which is accomplished in about eighteen and a half years. Each node, or point where the moon's orbit crosses the plane of the earth's orbit, which is indicated by the sun's apparent annual path in the heavens, moves westward about nineteen and a half degrees every year; the node, therefore, goes this much to meet the sun, as it were, in his annual course; so that the time occupied by the sun, from his leaving the position of the node till he arrive at the node again, does not amount to a whole year, but only to about three hundred and forty-six days. Now it so happens that nineteen of these periods are almost exactly equal to two hundred and twenty-three lunations, or revolutions of the moon around the earth. It is evident, therefore, that if the sun, in his annual path, pass the node at a certain point in the heavens, at the beginning of the first period of 223 lunations, he will pass the node at the same point at the beginning of the second period of 223 lunations; in short, that the sun and the moon will occupy the same point in the heavens at the commencement of every period of this duration, and that during the whole period they will have passed each other, or been in conjunction, nearly 223 times. It is when the sun and the moon meet at the moon's node that an eclipse of the sun happens; and since their whole cycle of meetings or conjunctions will have been accomplished in the above

period, the same number of eclipses of the sun will occur, and at the same times, in one single period of 223 lunations, as in every succeeding period; if, therefore, an eclipse of the sun happen in the second year of this cycle, it will happen in the second year of every succeeding cycle, and so on. This period was known to almost all the ancient nations; it was named *Saros* by the Chaldeans, and was the only means they had of predicting eclipses.

Again, it so happens that in nineteen years there are exactly two hundred and thirty-five new moons; so that, if the new moon occurred on the first day of any year, it would occur exactly on the first day of the twentieth year afterwards. Hence, if all the moon's changes for the period of nineteen years be known, they may be calculated with tolerable accuracy for every succeeding period of the same duration, as they will happen at the same times. This period was also known to the ancients, and was used for ascertaining the age of the moon at any future period. It was discovered by Meton, an Athenian, hence denominated the *Metonic cycle;* it was adopted in Greece on the 16th of July, 433 years before the Christian era, for the regulation of the calendars; and it was inscribed on the walls of the temple of Minerva in letters of gold. From this circumstance, the number which denotes the year of the lunar cycle, and which is still given in our almanacks, is called the *golden number.*

These are a few of the moon's irregularities which arise from the mutual action of the sun and the earth impeding her motion, and diverting her from her continuous course around the earth, and which are the result of the great law of universal gravitation. To calculate the moon's exact place in the heavens at any future period, therefore, requires the highest powers of mathematical analysis to be applied to her motions, by those who have qualified themselves for the task by a long and difficult course of preparatory study. But so accurately is this accomplished by modern astronomers and mathematicians, that they have constructed tables by which they can predict for thousands of years to come, not only the place of the moon, but the "precise moment of the passage of any one of the stars over the meridian wire of the telescope of the transit instrument, with such a degree of accuracy, that the error would not be so great as to remove the object through an angular space corresponding to the semidiameter of the finest wire that could be made; and a body which, by the tables, ought to appear in the transit instrument in the middle of that wire, would in no case be removed to its outer edge. The astronomer, the mathematician, and the artist, have united their powers to produce this great result. The astronomer has collected the data, by long continued and accurate observations on the actual motions of the heavenly bodies, from night to night, and from year to year; the mathematician has taken these data, and applied to them the boundless resources of geometry and the calculus; and finally, the instrument-maker has furnished the means, not only of verifying these conclusions, but of discovering new truths as the foundation of future reasonings."

It will be recollected that, by the law of universal gravitation, not only does a large body attract a small one, but that "every particle of matter in the universe attracts every other particle with a force directly proportioned to the mass of the attracting particle, and inversely to the square of the distance between them." Theoretically, therefore, in accordance with this law, not only ought the earth to attract the moon, altering and disturbing her otherwise regular motions, from the varying circumstances under which this attraction operates, but the moon ought to exert an attractive influence on the earth, tending to disturb its motions, and to draw it away from its continuous onward course. This in reality takes place; but from the small size of the moon compared to the earth, the effects of the former on the latter are not nearly so appreciable; that such is the case, however, is proved by a well-known and easily recognised phenomenon, which has been observed, although its cause was not understood, from the most remote period in the history of mankind. We mean the phenomenon of the *tides* of the ocean, an explanation of which will occupy the remaining portion of this chapter.

Herodotus and Diodorus Siculus allude to the daily flux and reflux of the waters of the Red Sea—to its great and rapid tides—without attempting to assign any cause for them. Pytheas of Marseilles, a contemporary of Alexander the Great, appears to be the first individual mentioned in history, who ascribed the tides to the influence of the moon. Pliny, in his description of the tides, broadly asserts that they are caused by the action of the sun and moon. Des Cartes fancied the tides were produced by the pressure of the moon. Galileo erroneously ascribed them to the action of centrifugal force caused by the earth's motion. But, as we have already mentioned, Kepler was the first who hit upon the true cause of the phenomenon; and after the discovery of the proof of universal gravitation by Newton, it was not difficult to demonstrate that the tides are a direct consequence of the universal law, resulting from the attraction of the sun and moon, but more particularly of the moon, exerted on the waters of the ocean.

Every one knows, that by the tides are meant that alternate rising and falling of the waters of the ocean, which are observed to occur to a greater or less extent over the whole globe. The sea by degrees rises, or *flows*, as it is called, during six hours; it continues stationary about a quarter of an hour; and then subsides, or *ebbs*, during the next six hours, to commence rising again after a brief interval. Its greatest elevation is called *high* water, and its least elevation, *low* water; while the more than usually high and low tides which occur twice every month, are called *spring* and *neap tides.*

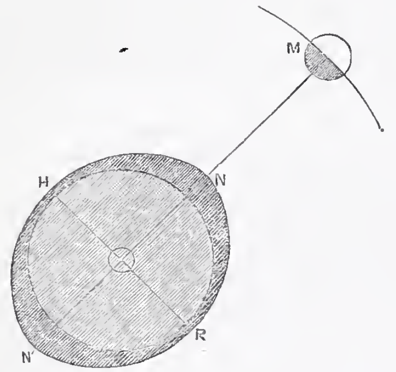
Many persons have a strange difficulty in comprehending the phenomena of the tides, and are unwilling to attribute their cause to the great law of universal gravitation. That the moon or the sun, by the influence of their attraction, could raise the waters under them so as to produce high water, they can easily understand; but that this same attraction should also heap up the waters on the opposite side of the earth, so as to produce high water there at the same time, they look upon as an impossibility. Again, they urge the difficulty, that at some places on the earth there is scarcely any tide at all, while at other places it rises to seventy feet. The periods of the occurrence of the tides, also, they show not to be in accordance with the times of the moon's passing the meridian of different places; high water not taking place for six, ten, or even fifteen hours after the moon passes the meridian of that place.

By taking a proper view, however, of the mode in which an external attracting influence operates upon so moveable a body as the water of the ocean; and taking into account, also, the disturbing or counteracting causes which are in operation to interrupt the regularity of the tides on the different portions of the earth's surface, not only may the phenomena of the tides be easily understood, but their apparent irregularities can be accounted for with little difficulty.

We must consider, then, what would be the effect of the moon's attraction upon the form of our globe were it composed wholly of water. It is obviously apparent that, from the circumstance of one side of this globe being more distant by the whole length of its diameter than the other side, the strength of the moon's attraction at these two surfaces will be very different; according to the law of gravitation, the side nearest the moon will be attracted by a certain amount of force, while this force goes on diminishing in proportion to the square of the distance, till, at the side farthest off, the attraction will be very much less. The effect of this unequal attraction upon a moveable globe like water, would obviously be to alter its shape from a spherical to an oblong form. By a greater attraction, the side nearest the attracting body will be drawn out or elongated; by a less attraction, the side farthest off will be left behind, and in this way it will also be elongated; both sides will be drawn out an equal distance, the intermediate surfaces will be flattened, and thus will a spherical body become an oblong ellipsoid, with its longer axis always directed to the moon. It is precisely this effect that is produced by the attraction of the sun and moon upon the waters of the ocean. Were the whole earth covered by

a certain depth of water, this water would assume an oblong form; high water would always occur soon after the moon passed the meridian, and it would be composed of a single tide wave, regularly following the moon's course around the globe; and in consequence of the moon's attraction upon the earth acting powerfully upon the side nearest her, the earth would be drawn into, and kept in the middle of this watery envelope; so that the depth of water on opposite surfaces would be equal, either high or low water occurring on opposite sides of the earth, simultaneously. Thus, in the following diagram, in which, for the purpose of illustration, the elevation and depression of the water is represented in a greatly exaggerated form, the waters are seen heaped up at Z, from a certain amount of attraction exerted by the moon, as well as heaped up at, N being left behind, as it were, by a diminished amount of attraction; from the sides, H and R, the waters are consequently drawn away, and low water is produced; while the earth is kept in the centre of this watery envelope by the attraction of the moon, which must necessarily be exerted much more powerfully upon the side of the earth next her, than upon the waters at N.

Fig. 26.

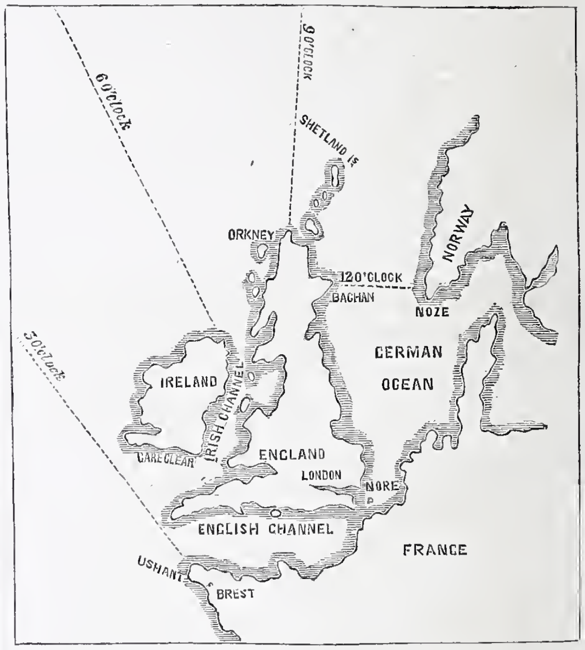


But the whole earth is not covered by a zone of water of a certain depth; continents of land, islands, peninsulas, promontories, &c., interfere with the theoretical movements of the tides; besides, the inertia of the waters prevents their instantaneously obeying the moon's attraction, and the friction which they must overcome at the bottom of the ocean still farther retards their regular progress; so that it is not until several hours (the number of which varies in different localities) after the moon has passed the meridian, that high water occurs in any place. In addition to these impediments to the regular course of the tides, we must mention the varying force and direction of the action of the winds, as well as the many strong currents and counter-currents in the ocean.

In narrow seas, channels, and gulfs, the tides rise to a far greater height than in the main ocean. The average amount of tides for the whole globe is only two feet and a half, while in the Bay of Fundy, on the coast of Nova Scotia, the tide rises to the enormous height of seventy feet. At the mouth of the Wye in England, it rises to about fifty feet; at the mouth of the Avon to forty-two feet; at Milford Haven to thirty-six feet; at London and Beachy Head to eighteen feet; at the Needles, off the Isle of Wight, to nine feet; and at Weymouth to seven.

The only portion of the ocean where the waters are left nearly unimpeded, and where they very quickly obey the influence of the moon's attraction, is the southern part of the Pacific, including the Indian Ocean; and here we have a regular and single tide wave following the moon's course, and running from east to west. Along the whole south-east coast of Africa, from the Cape of Good Hope to the mouth of the Red Sea, it is high water at exactly the same time; but it is quite different in the North Atlantic; high water occurs there at very various times, being always later as we proceed northward. The tide wave, when it reaches the Cape of Good Hope, must proceed in a northerly direction, and it takes fifteen hours to travel to the British Islands. Suppose the moon to pass the meridian of Brest, at the most north-westerly point of the French coast, at twelve o' clock noon, it would be high water at three p. m., while the tide wave proceeding in a north-easterly direction comes in contact with the British Islands, by which it is divided into three branches; one flows up the English Channel; a second advances through St. George's Channel into the Irish Sea; while the third and largest sweeps the northern shores of Ireland and Scotland, passes the Shetland Islands, and flows slowly into the German Ocean to meet the first branch at the mouth of the Thames. As may be supposed, these tide waves take a considerable time to travel this distance; the principal branch reaching the north coast of Ireland at six o'clock, the north point of Scotland at nine o'clock, it enters the German Ocean at twelve o'clock, and in about eleven

Fig. 27.



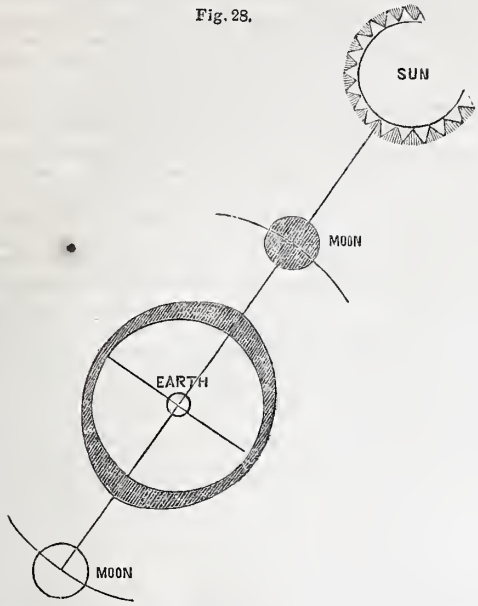
hours afterwards, or twenty hours after it passed the south-west of Ireland, the tide wave reaches the mouth of the Thames.

As yet we have scarcely alluded to the influence of the sun as a cause of the tides; he acts in a precisely similar manner to the moon, but with an amount of attraction only *one-third* as great. We might at first sight suppose, from the enormous size of the sun, that he ought to exert as great an attraction as the moon upon the waters of the earth. It is his immense distance, however, which causes a much greater uniformity, as well as a much less force of attraction to be exerted by the sun than by the moon upon the waters surrounding the earth. It is not the absolute *amount* of attraction exerted by the moon, but the *inequality* of this attraction on different parts of the earth, that both produces the tides, and is the cause of the moon's superior influence.

The attraction of the sun, then, is capable of producing a tide wave on opposite sides of the earth, though only one-third as high as that produced by the moon. Sometimes the sun and moon act in conjunction, as at new and full moon, and at such periods of course the tides rise much higher, and are denominated *spring tides;* they occur twice every month. At other times these bodies act in opposition, as at the moon's quadratures, and at such times the tides neither rise so high nor fall so low as at other times.

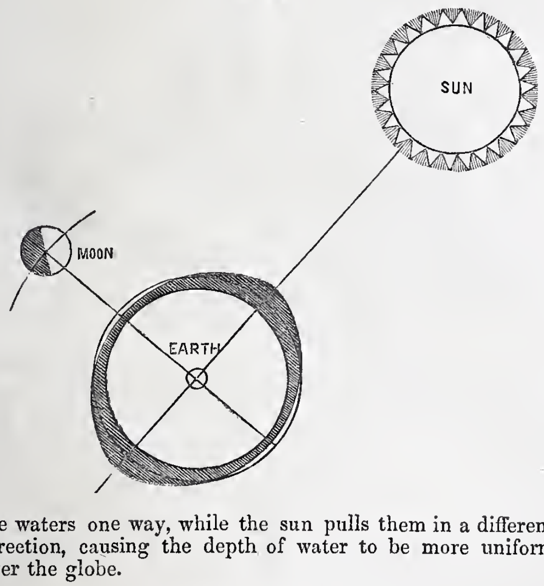
The following figure gives a plain representation of the action of the sun and moon when they act in conjunction, at new and full moon.

Fig. 28.



In figure 29 is shown the effect of the attraction of the sun and moon upon the waters of the ocean when these bodies act in opposition; here the moon is pulling the earth and

Fig. 29



the waters one way, while the sun pulls them in a different direction, causing the depth of water to be more uniform over the globe.

OF THE PORCELAIN AND POTTERY MANUFACTURE.

ARTICLE I.

THE PORCELAIN MANUFACTURE—TESSELATED TILES.

Under the above head, we propose to give a rapid sketch of an important department of manufacture, illustrative of the chemical agency whereby crude materials are brought into a homogeneous form, and thence brought to those useful states which are so familiar to us in every-day life: we allude to *porcelain* and *pottery*, a kind of manufacture chemical and mechanical by turns. Several interesting details with regard to the antiquity of this art are given by the late Mr. Parkes in his Chemical Essays. He considers it "probable that the early inhabitants of the world arrived nearer to perfection in the modelling of clay, and in the making of earthenwares, than in the management of any other manufactures; for in the kingdoms of China and Japan, not only common earthenware, but even porcelain of very excellent quality, was made long before the commencement of the Christian era." We will first notice the porcelain manufacture, properly so called, as carried on at Worcester, Derby, and other places; and then the larger and more commercially important pottery manufacture, as associated especially with the Staffordshire district.

PORCELAIN.

Those among our readers who may have enjoyed the pleasure of witnessing the great Exhibition in Hyde Park, cannot fail to have admired the magnificent specimens of English porcelain there exhibited—the Parian figures, and other models of statuary, the jars, cups, vases, urns, &c., which figured in the Ceramic department. This beautiful manufacture is still comparatively recent in England. China has, by a sort of prescriptive right, been deemed the land of porcelain, the country whose inhabitants occupy the first rank in the production of this most delicate, chaste, and elegant semi-transparent material. Thanks to the inquiries and ingenuity of travellers, manufacturers, and men of science—who have discovered the nature of the principal substances employed by the Chinese, the localities in which they may be found in Europe, and who have employed the services of painters far more skilful than any to be found in China — our country now produces specimens of porcelain possessing all those claims to admiration which the "Celestial Empire" has put forth for its manufacture, and—in respect to pictorial embellishment—others in which our Asiatic friends cannot for a moment share.

In this respect the English productions displayed in the Crystal Palace might challenge a triumphant comparison with even the magnificent porcelain glories of the celebrated Chinese Exhibition, which some of our readers may have inspected.

Everybody knows that porcelain is the same material as that which is commonly termed 'china' (a name which in itself does homage to the original producers of the substance), but the meaning of the name is not so well known. One authority* says—"The Portuguese traders were the means of introducing the fine earthenwares of China into more general use in Europe; and the name assigned to the fabric, as distinguishing it from the coarser descriptions of pottery of domestic manufacture, was most probably given by them—*porcellana* signifying, in the Portuguese language, a cup;" while another authority† states—'It has been satisfactorily shown by Marsden, that the word porcelain, or *porcellana*, was applied by Europeans to the ware of China from the resemblance of its fine-polished surface to that of the univalve shell so named; while the shell itself derived its appellation from the curved or gibbous shape of its upper surface, which was thought to resemble the raised back of a *porcella*, or little hog." Leaving the reader to select between the 'cup' and the 'little hog,' as the forerunner of the name, we will quit this matter, and describe the general arrangement of a porcelain manufactory.

First, there is the building in which the crude materials are brought into a plastic or working state. Here we see a ponderous circular stone, many tons in weight, working round in a circle on its edge, and crushing beneath it the stony ingredients of the porcelain. Then, in another part of the building, is a circular vessel, provided with a stirring apparatus, for further preparing the substances by the aid of water. The mixing-room, in another place, contains the vessels in which the pounded ingredients are worked up into a smooth kind of clay, fitted for the purposes of the workman. Following the

* 'Lardner's Cyclopædia'

† Davis: 'The Chinese,' chap. xvii.

prepared material to the hands of the workman, we visit the 'throwing-room,' where the remarkable process of forming circular vessels is conducted. This is a long and busily occupied shop, containing a great number of men employed as we shall describe presently. Kilns in great number are disposed conveniently, with respect not only to the 'throwing-room,' but to the other workshops; for there are 'biscuit-kilns,' 'glaze-kilns,' and 'enamel-kilns,' according to the state of the process in which heat has to be applied to the ware. Various rooms, called 'placing-room,' 'dipping-room,' 'white-ware room,' 'modelling-room,' 'moulding-room,' 'pressing-room,' &c., are disposed round the open area, for the prosecution of various processes in the course of the manufacture; to which succeed others known as the 'painting' and 'burnishing' rooms, in which those elaborate decorations are given to the manufactured article which form one of the most marked features of distinction between it and common pottery-ware. Then we come to the warehouses in which the finished product is stored. Lastly, there are shops, drying-rooms, and kilns, for the manufacture of the 'tessellated tiles,' which are now becoming so extensively used.

We have glanced at the buildings, and now let us glance at the workmen, and the remarkable processes by which the costly specimens of porcelain are produced. The rough ingredients, too, must have a passing notice.

The ingredients to form porcelain may to many persons seem rather strange. They consist of common flint, flint in the calcined state, Cornish stone, Cornish clay, and calcined bone, all ground and mixed together with water, so as to form a beautifully fine and plastic clay. Numerous and intricate have been the researches into the respective value of different kinds of material, and the particular quality which each one gives to the porcelain. The clay employed, as its name imports, is brought from Cornwall, and is found to possess qualities wanting in most other kinds of English clay. For the commoner kinds of pottery, clay brought from Dorsetshire and Devonshire is largely employed; but for the more exquisite specimens of porcelain this Cornish clay is preferred. Until about a century ago, the strangest views were entertained in Europe respecting the composition and nature of Chinese porcelain.

The subject remained enveloped in mystery till Francis D'Entrecolles, who had resided many years in China as a Christian missionary, had the address to procure specimens of the materials used by the natives in their porcelain; and these he transmitted to France, with some account of the processes practised by the Chinese. When the specimens arrived in France, the celebrated Reaumur undertook a series of experiments to discover the method of imitating the Chinese productions. It was not till after many researches that he succeeded in accomplishing the main object he had in view, and found that the mixture of the two peculiar kinds of earth found in China, called *pe-tun-tse* and *kao-lin*, produced porcelain. It then became an object to discover whether any earths similar to these existed in Europe; and at length Mr. Cookworthy, about ninety years ago, discovered in Cornwall two kinds of earth which nearly answered the desired character. The following account of this clay is given in the official catalogue of the Great Exhibition of 1851:—

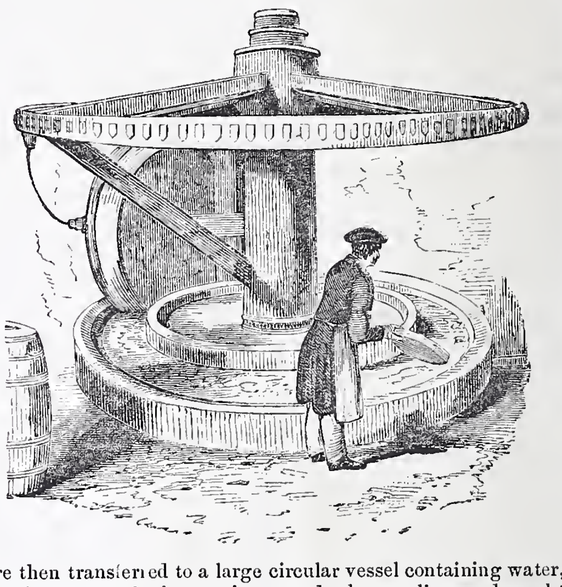
"The Cornish clay is the best, and is technically termed by potters 'China clay.' It is the decomposed felspar of the granite, and is prepared by the clay merchants themselves in Cornwall, prior to its being sent to the potteries. Huge masses of white granite abound in Cornwall, which is in some parts found partially decomposed; and when this is the case, the mineral is raised and prepared for the potter's use, it having been discovered by Mr. Cookworthy of Plymouth, in 1765, that it furnished the true *kao-lin*, and also the *pe-tun-tse* of the Chinese.

"The following is the method of preparation:—The stone, having been broken up by a pickaxe, is laid in a stream of running water; the light argillaceous parts are thus washed off, and kept in suspension; the quartz and mica being separated, are allowed to subside near the place where the stone was first raised. At the end of these rivulets are a kind of catch-pools, where the water is at last arrested, and time allowed for the pure clay with which it is charged to form a deposit, which being effected the water is drawn off; the clay is then dug up in square blocks, and placed upon a number of strong shelves called 'linnees', so fitted as to allow a free circulation of air, in order that the clay may be properly dried. Thus prepared it is extremely white, and when crushed forms an impalpable powder. It is forwarded to the potteries under the name of China clay."

From the date of Mr. Cookworthy's discovery to the present time, various improvements and additions have been made in the ingredients employed, with a view to produce porcelain possessing hardness, strength, firmness of texture, whiteness of colour, and a capacity of receiving and retaining colours and gilding on its surface. The Cornish clay is by far the most costly clay employed in such works; but for the finer porcelain it is deemed indispensable. We may perhaps say, in accounting for the respective value of the ingredients, that the clay gives the plastic or working quality, the flint imparts the vitreous or strengthening quality, and the bone aids in producing the semi-transparency for which porcelain is so deservedly admired.

The ingredients have different degrees of hardness, but all must be reduced to an impalpable powder before being mixed. The China clay is already partially prepared, but the other ingredients require to be crushed. For this purpose they are laid on a circular bed, as represented in the cut, and ground by the pressure of the bulky and ponderous stone roller. They

Fig. 1.



are then transferred to a large circular vessel containing water, and by means of stirrers, sieves, and other appliances, brought into the condition of a creamy liquid, totally free from any gritty particles. It is astonishing to see the degree of fineness thus produced, as manifested by the extreme minuteness of the meshes or interstices of the sieve through which everything must pass before being deemed fitted for the manufacture.

Various depositories or receptacles are provided, in which the ingredients are placed separately during the course of their preparation; and from these they are conveyed to the 'mixing-room,' where they are combined together. Here the experience and judgment of the manufacturer are brought into operation: he has to determine not only the number and kind of ingredients which will produce a ware fitted for service, but also the proportions in which these ingredients are to be combined. It is not improbable that each eminent firm has a recipe peculiar to itself, as is known often to be the case in the glass manufacture, and many other manufactures in which several ingredients are employed. The mixture presents the appearance of a kind of drab-coloured liquid, which is then evaporated to a certain degree of thickness or stiffness by heat applied beneath it. In short, it is by the agency of heat that the cream-like liquid

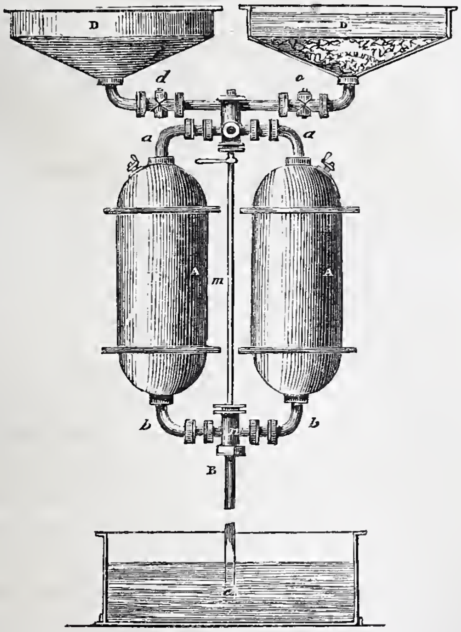
becomes a plastic workable clay, fitted for the hands of the potter. Constant attention is necessary throughout this process, to equalize the rate of evaporation, and to retain the ingredients in perfect combination while it is going on.

The creamy substance, before its evaporation to bring it to the proper consistence, is termed *slip.* To undergo this operation, after being properly strained and purified, it is removed to the *slip-house*, and boiled in the *slip-kiln;* the former a long low detached building, with the tiles placed half-way apart to allow the steam to escape; the latter, a series of long brick troughs, with flues under them, for heating the mixture to the boiling point. The slip, being constantly stirred to keep the heavier flint from subsiding, remains in the kiln about twenty-four hours, when bubbles of steam cease to be formed on the surface, and the mass acquires a sufficiently doughy consistence for the potter's use.

In countries where fuel is scarce, the evaporation of the slip is performed by exposing it in vessels in the open air, or by the application of mechanical pressure. The former method is slow, and is therefore generally combined with another. When a certain quantity of water has been got rid of by the natural process of evaporation, the paste is put into thick plaster moulds, which, by absorbing more of the water, bring it to the proper consistence. But a better and more expeditious method is, by subjecting the slip to mechanical pressure. For this purpose it is put into sacks or mats, of strong and closely-woven texture, and then subjected to the action of a screw-press or loaded lever.

The economizing of fuel is an object of the greatest importance, both in a natural and business view; and although, from the abundance of coal in England, the process of evaporating by means of heat is not so expensive as it would be in some countries, yet it appears to involve a needless expenditure, and not to be attended with any advantages over the system of filtration by means of mechanical pressure. Even the simple pressure of the atmosphere may be applied with success to the same purpose, by means of the apparatus shown in the annexed engraving, fig. 2. A A are the filtering

Fig. 2.



vessels, connected by tubes at the bottom with cylindrical vessels, B B, which terminate below in tubes that meet in a long pipe descending into a cistern of water, D. The filtering vessels, A, are furnished with an iron grating, *m*, at their lower part; and a bed of pebbles, *n*, is made to cover the grating and the whole of the conical part of the filter. The grating and the pebbles are covered with a cloth of thick spongy felt, which is firmly secured at the edge of the filter; and over the whole is another cloth of hemp, for receiving the slip. The atmospheric pressure is made to act by filling the vessels, B, with water, and then securing the stopcocks, so that, as the water descends in the vessels, B, the weight of the atmosphere pressing on the liquid in the filters, A, is not counteracted from below. The pipe descending to the cistern, D, is made about thirty-six feet in length, which is more than the length of the highest column of water supported by atmospheric pressure. The water will therefore descend from the vessels, B, into the cistern, leaving a vacuum in these vessels, and in the upper part of the pipe, which is shown broken off in the figure. This vacuum is preserved, while removing one charge of slip and introducing another, by turning the stopcocks, *o o*.

When the slip has been brought to the proper consistence by one or other of these processes, it is removed to a part of the slip-house, where it is cut up into wedges by means of a spade, and these are dashed against each other to get rid of vesicles or air bubbles, which would produce blisters in the ware. This process is termed *wedging*, and ought to be carried on at intervals during several months. In China, a store of clay is sometimes prepared in this manner fifteen or twenty years in advance. During this *ageing* of the paste, a kind of fermentation goes on, by which the clay is greatly improved both in texture and colour.

To the 'throwing-room' and the 'potter's wheel' we now direct our attention, where a process is conducted which has never failed to excite the astonishment of a spectator who witnesses it for the first time; nay, there are many who find the comprehension of the process almost as difficult after many visits as after the first. Never does any one agent appear a more complete master over another than the potter is of his clay: he seems as if he could do anything, everything with it. At one moment his mass of clay is a shapeless heap; at another a circular cake; then a ball; then a pillar or cylinder, hollow or solid; then a jug; then a basin; a sudden turn converts it into a bottle, or a plate, or a saucer. His hands work and form the plastic material with a rapidity almost inconceivable; and we often doubt where the clay seems to come from, and whither it goes, when one form is being exchanged for another. It is true that, in practice, the potter does not give all these several forms to one individual mass of clay; but a visitor has frequently an opportunity to see that the man *can* do so. What a pity, some may say, that such an elegant process (for such it assuredly is) should be thrown away upon wet dirty clay! but in truth the peculiar state of the clay is the very circumstance which gives to the potter such a command over it. Let us look at the arrangements of the potter's shop before we describe his operations.

Why such a room should be called a 'throwing-room,' or why the formation of circular vessels should be called 'throwing,' it does not seem very easy to determine. There is a circular motion in pottery-throwing, and also in silk-throwing, but why the same term should be applied in both cases, or why applied at all, we do not see. We believe, however, that 'throw' is a provincial name for a lathe; and if so, an explanation is easily provided, by considering the potter's wheel as a lathe or throw. The throwing-room, however, be its appellation good or bad, is a room containing a great number of benches and pieces of apparatus, at which men are employed making circular articles of soft porcelain.

Scarcely any other machine has lived so long and undergone so little change as the 'potter's wheel.' On the Egyptian monuments, and on other records of antiquity, there are representations of the potter's wheel similar in all the essential particulars to those of our own day; indeed nothing can be more simple than the construction. In the potter himself, and not in the wheel, lies the merit of the work executed. The potter sits on a kind of stool or bench, immediately behind a small circular whirling-table. His knees are placed one on each side of the central support of the machine, so as to give him a command over it. This, which we have called the whirling-table, is simply a circular piece of wood, whose breadth is sufficient to support the widest vessel that is to be made:

it is fixed on the top of a vertical stem or shaft, so that, if the shaft be made to rotate, the piece of wood must rotate likewise. The apparatus is rather below the height of a common table. The clay which is to be formed into a vessel is put upon the circular board, and there remains till fashioned; the board and the shaft beneath being made to rotate horizontally, while the potter with his hands gives the form to the mass of clay.

Every potter, or 'thrower,' is attended by two boys, who are called the 'ball-maker' and the 'wheel-turner.' The former of these has before him or near him a mass of prepared clay, having precisely the quality and consistence required for the potter's operations. He separates the clay into smaller masses, each suited to the manufacture of one particular kind of vessel, and works it up into a rude kind of ball, convenient to be handled by the thrower. He is in every way the servant or helper to the thrower. The services of the wheel-turner depend on the manner in which the circular piece of wood is made to rotate. In the early state of the porcelain manufacture in England, the perpendicular shaft beneath the board was put in motion by a wheel provided with spokes, which the thrower moved with his foot; the labour, however, was so great, that this method became unsuited to the production of large articles. Another method in past times was, to have a crank in the middle of the shaft, with a long rod working upon it, and motion was given to the lathe by the rod being pushed backward and forward. The customary mode at the present day is, however, to have a rope passing from a pulley upon the perpendicular shaft to a large wheel at a distance, which wheel is turned by a boy under the directions of the thrower.

With this very simple kind of lathe, and with a few small tools still more simple, does the workman proceed to fashion all those articles of porcelain which are circular in their form, whether cups, basins, or vessels of any other kinds. When the shape is too diversified to be deemed circular, other modes of formation must be adopted, of which more hereafter. Let us suppose, as an example, that a hemispherical basin is to be formed. The man places a mass of clay, in size and consistence suited for the purpose, upon the bed of his lathe or wheel, striking it down rather forcibly as a means of making it hold firmly to the wood during the process of formation. He gives directions to his wheel-turner to set the machine in motion, and then forms the shapeless mass into a vessel, chiefly by his hands. With his hands, wetted in an adjacent vessel of water, he presses the clay while rotating, and brings it into a cylindrical form; this cylinder he forces again down into a lump, and continues these operations—squeezing the clay into various shapes—until he has pressed out every air-bubble from the body of clay, a precaution of very great importance. Then pressing the two thumbs on the top of the mass, he indents or hollows it, as a first germ of the internal hollow of the vessel. Once having the least semblance of a cavity within, he proceeds with a rapidity almost marvellous to give both the outward and the inward contour to the vessel. With the thumbs inside and the fingers outside, he so draws, and presses, and moulds the plastic material, as to give to the outside a convexity, to the inside a concavity, and to the whole substance a uniform consistency, without breaking the clay or disturbing the circular form of the vessel. It will be seen, on a moment's consideration, that this circular form is due to the rotation of the clay, while the fingers and thumbs are stationary, just as a turner holds his cutting-chisel stationary while the piece of wood is rotating.

During the pressure of the hands upon the clay, a minute change in the amount or direction of the pressure would transform the basin into a saucer, or into any other vessel whose degree of curvature is very different from that of a basin. The oddness of these transformations might often make a spectator smile, were not his admiration excited by the cleverness and dexterity of the workman who produces them. According to the shape and size of the vessel, the thrower requires the wheel and the mass of clay to rotate with varying degrees of velocity, in which he instructs his wheel-turner.

The general contour of the vessels, inside and out, is given by the thumbs, fingers, and palms of the hands. But as this could not insure accuracy sufficient, the workman is provided with small pieces of wood called 'profiles,' or 'ribs,' each of which is shaped in accordance with either the exterior or the interior of some particular kind and form of vessel. Holding one of these ribs in his hand, and applying it to the surface of the clay, the workman scrapes off the superfluous portion at any protuberant or misshapen part, and makes the whole circumference conform to the shape of the rib. The fragments thus removed, technically called 'slurry,' he throws aside among the unused clay. If a number of vessels are to be exactly the same size, the workman sometimes fixes pegs in the stand on which the clay is placed, which act as a guide to him in regulating the diameter to which the clay is to be expanded, and beyond which it must not reach. When the vessel, by the aid of the hands and the small working tools, is formed, it is cut from the supporting piece of clay, or from the board, by means of a piece of brass wire, much in the same manner as barrelled butter is cut into slices, and the newly-formed vessel is placed on a board or shelf to dry.

In this manner vast varieties of vessels are formed, comprising all those which present, both on the exterior and the interior, a uniform circularity. And, indeed, not only are vessels thus formed, but masses of clay are similarly brought into a cylindrical form, as a nucleus from which ornamental articles may afterwards be produced at the turning-lathe. Within the last few years the use of porcelain has greatly extended, in relation to articles both useful and ornamental. Candlesticks, taper-stands, fancy baskets, door-handles, finger-plates, and a host of other articles, are now made of this material; and if the form is such as can be given by the lathe, a mass of clay is first worked by the hand into something like a cylindrical shape, as a preparative for the operations of the turner.

The operation of *turning* these articles is effected very much in the same manner as the turning of wood. They are allowed to remain until, by the evaporation of moisture from the damp clay, they have acquired a degree of dryness which is known among the workmen as the 'green state,' in which state the shaping and smoothing of the surface are better effected than when the clay is either damper or drier. As a turner in wood can produce an internal cylindrical cavity as well as a circular exterior, so can the porcelain-turner; and it is in this way that candlesticks and similar articles are brought to the required shape.

We have now, in supposition, made circular vessels, and turned them to the proper shape and smoothness. But before we follow them through their subsequent progress, it is desirable to witness the production of those articles which neither the potter's wheel nor the lathe will produce; articles which exhibit, in an especial degree, the magnificence and delicacy of the finer kinds of porcelain. This will take us to the workshops of the 'pressers,' the 'mould-makers,' and the 'modellers;' for the decorated articles are produced by pressing, or by pouring clay into moulds, which moulds must previously be made from models, and which models must have been before formed by hand. Hence the modeller is the all-important workman, whom we must first visit.

In this department, whatever our Schools of Design, or education, or natural ability could afford, in the development of a knowledge in elegance of form, is important and valuable. The modeller, from drawings made either by himself or by others, has to build up in clay the exact representative of the article to be formed in porcelain. From the handle of a teacup, up to the most elaborate combination for a piece of drawing-room porcelain furniture, the modeller has to prepare an accurate original in soft clay. Provided with a supply of clay, especially prepared for this kind of work, and with a few simple tools, he elaborates the various parts of his design, whether animals, fruit, flowers, foliage, architectural ornaments, arabesques, or any of the countless varieties of decorative devices; building up his model piecemeal, and carving or cutting out the parts as he proceeds. It has been aptly observed by Mr. Porter, that "the taste of the modeller is put in requisition; calling for the execution on his part of a high degree of skill and ingenuity in forming patterns, and adapting to them appropriate ornaments. To be a perfect modeller, in the higher branches of the art, a man should have an acquaintance with the best produc-

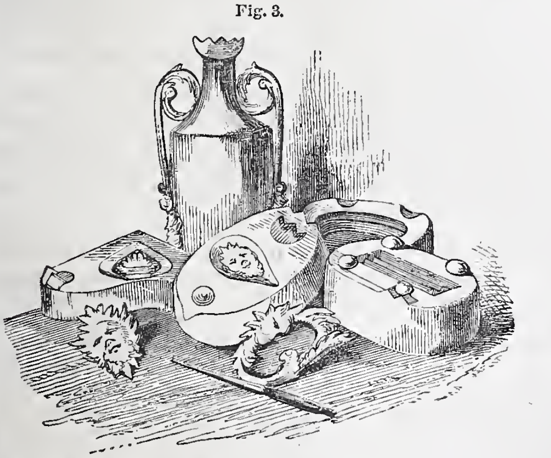
tions of the classic climes of Greece and Rome; he should be master of a competent knowledge of the art of design; his fancy glowing with originality, tempered and guided by elegance and propriety of feeling, and restrained by correctness of taste and judgment. To a man thus gifted, the plastic and well-tempered material wherewith he works offers little of difficulty in the execution of his conceptions."

It is only in the costly articles which require *casting* that the model is thus elaborate: when it can be produced by *pressing*, the preparation of the model is generally more simple. The difference between these two modes of manufacture is this; that, in pressing, the shallowness of the mould is such that clay, in its usual plastic state, can be pressed into all the minute devices of the mould; while, in casting, the mould is so deep and elaborate that the clay has to be poured into it in the state of a cream-like liquid. Plates, saucers, oval vessels, lids, spouts, handles, and a large variety of articles which are too irregular to be produced at the potter's wheel and the lathe, and yet not so complex as to require casting, are produced by pressing. But both for pressing and for casting moulds must be made, and these moulds are reversed copies of models produced by the modeller; so that this workman's services are required for all.

Plaster of Paris, prepared in a particular way, is the substance of which the moulds are made. The making of the moulds is quite a distinct occupation from that of modelling, and is carried on in a different part of the factory. A casing of clay is first formed and securely fixed round the model, leaving sufficient space between it and the model for the substance of the mould. The plaster of Paris, being mixed with water to a cream-like liquid, is then poured into the vacant space. In a very short time, in virtue of the well-known qualities of this substance, the plaster solidifies into a compact mass, which is easily separable from the model. The interior of this mould is then found to give a perfect counter-representation of the exterior of the model, in all its minuteness of detail. The model is lastly dried, to prepare it for further use.

For pressing, the mould is sometimes made in two parts, one half of the figure being on one side, and the other half on the other; the two being made to fit accurately together. Clay is pressed into each half of the mould, and cut off flush, so as to have no superfluity; and the two halves of the mould being brought closely together, each piece of clay receives its impress from the half of the mould in which it lies, and the

Fig. 3.



two pieces are at the same time joined together: so that one piece is produced, presenting a fac-simile of both halves of the mould. This mode is adopted in the preparation of a large diversity or variety of articles. Another arrangement, for the production of plain handles, spouts, &c., is to force clay through an orifice in the bottom of a cylinder, the orifice having that shape which is to be given to the clay. A third arrangement, where one surface of a shallow vessel, such as a saucer or a plate, requires to be moulded, while the other can be formed without a mould, is to lay a flat piece of clay on the mould, press it down with a wet sponge, and give a proper form to the exposed surface by a profile or gauge applied to the wet clay while the latter is revolving. The annexed cut (fig. 3) represents a few ornamental articles which required to be produced by pressure, and the moulds used in the pressing.

So varied and numerous are the articles now made of porcelain, that it would be utterly impracticable to classify them all in respect of the mode of manufacture; but it will suffice to say, that all are produced by one or other of the modes above noticed, viz., throwing at the wheel, aided by profiles or gauges; turning at the lathe; pressing through an orifice in a cylinder; pressing one side on a mould, while the other side is fashioned by a gauge; pressing between two moulds, or the two halves of a mould; and casting while the clay is in a liquid form. In the last-mentioned mode of proceeding, the plaster of the mould quickly absorbs water from the liquid clay, which lies in contact with its surface, and brings it to a solid state; and a hardened shell having been thus produced, the subsequent arrangements are such as to make the cast either hollow or solid, according to its form and dimensions.

The articles which figured in the Great Exhibition under the head of Parian, Carrara, or Statuary Porcelain, are produced by casting. Of late, the application of porcelain to statuary has rapidly extended, and a number of beautiful objects in statuary porcelain were exhibited. Among these

Fig. 4.

was "The Prodigal's Return," by W. Theed,—one of the numerous statuary groups contributed by Mr. Copeland, Stoke-upon-Trent, and which is represented in fig. 4. Many difficulties of manipulation attend the production of such

objects, arising out of the shrinking of the clay when burnt. As the most direct method of illustrating this process, the writer in the Official Catalogue supposes the object under review to be a figure or group, and this he assumes to be two feet high in the model. "The clay—which is used in a semi-liquid state, about the consistency of cream, and called 'slip'—is poured into the moulds forming the various parts of the subject (sometimes as many as fifty): the shrinking that occurs before these casts can be taken out of the mould, which is caused by the absorbent nature of the plaster of which the mould is composed, is equal to a reduction of one inch and a half in the height. These casts are then put together by the 'figure-maker,' the seams (consequent upon the marks caused by the subdivisions of the moulds) are then carefully removed, and the whole worked upon to restore the cast to the same degree of finish as the original model. The work is then thoroughly dried, to be in a fit state for firing, as, if put in the oven while damp, the sudden contraction consequent upon the great degree of heat instantaneously applied, would be very liable to cause it to crack: in the process it again suffers a further loss of one inch and a half by evaporation, and it is now but one foot nine inches. Again, in the 'firing' of the bisque oven, its most severe ordeal, it is diminished three inches, and is then but eighteen inches high, being six inches, or one-fourth less than the original. Now, as the contraction should equally affect every portion of the details of the work, in order to realize a faithful copy, and as added to this contingency are the risks in the oven of being 'over-fired,' by which it would be melted in a mass, and of being 'short-fired,' by which its surface would be imperfect, it is readily evident that a series of difficulties present themselves which require considerable practical experience successfully to meet."

The species of porcelain to which these remarks refer, and of which the preceding figure is an illustration, is purely of English invention, and was introduced seven or eight years ago by some of our enterprising Staffordshire firms. It presents a great similarity of effect with the Parian and Carrara marbles, after which it is named. This effect is attained chiefly by the employment of a soft felspar in the porcelain, instead of Cornish stone, and from which it derives an agreeable yellowish-white tint. M. Arnoux, in his "Lecture on the Ceramic Manufactures of the Great Exhibition," read before the Society of Arts, June 2, 1852, remarks that, "if we compare our Parian with the biscuit made on the continent, we shall perceive the enormous difference in their relative appearance: while the continental biscuit acquires in firing a greater sharpness, it is the reverse in the Parian; whilst the former, with its hard, cold appearance, will reject the light, this light, penetrating into the latter to a certain depth, gives it a softness which has never been realized before." But to proceed with the common manipulations:—

Many a tea-drinker has probably marvelled how the handle of a tea-cup is produced; whether it is fashioned by hand out of the same piece of clay which forms the cup, or cast in a mould with it, or fixed on separately. The preceding details will have prepared us to understand the real state of the matter,—that the cup, if not too elaborate in form, is 'thrown' at the wheel; that the handle is pressed in a mould, and that the one is afterwards affixed to the other. Handles, spouts, knobs, and small raised ornaments, are all attached to the vessels in a similar way, and when the latter are in the 'green state,' between wet and dry. The cement employed is simply the creamy mixture of clay and water, employed in casting, and technically termed slip, which is applied to the two surfaces to be joined together, and which enables them to adhere permanently. The clay handle or spout is in such a soft state, that considerable neatness and dexterity are requisite, especially in curving the strip of pressed or moulded clay which is to form the handle—a process represented in the next cut, fig. 5. The raised or relief ornaments seen on articles of porcelain are made separately in a mould, and cemented on the vessel by the aid of slip, except when the vessel is of such a kind as to require to be cast or pressed, in which case the ornaments are generally made as part of the pattern itself in the mould. Taper-stands are now made, the construction of which illustrates conveniently the combination of the different modes of manufacture: for the lower saucer or dish is pressed in a mould; the nozzle is made into a 'solid' at the wheel, and

Fig. 5.

then turned at the lathe; the handle is formed in a double mould; and lastly, all these are joined together with slip.

Let us suppose, then, that we have traced all the various kinds of porcelain articles to a finished state, in respect of their form and decorations; the tea-pots furnished with handles and spouts, the cups with handles, the jugs with lips, and the more highly decorated articles provided with all which the 'thrower,' the 'turner,' the 'presser,' and the 'caster' can do for them. We shall next be prepared to follow them through the subsequent processes, which impart that exquisite appearance so especially belonging to porcelain.

Among the kilns or ovens employed in this manufacture are those called 'biscuit-kilns,' twelve or fourteen feet high, in which the ware is exposed to an intense heat. They are heated by fires ranged round the circumference, each kiln having eight fire-places. The whole interior capacity is fitted for the reception of the articles to be 'fired,' or 'baked.' Very great precautions are necessary in this process; for, if the smoke or flame from the fire attacked the porcelain, it would discolour it at once, and spoil it. To prevent this mischance, all the manufactured articles are put into receptacles called 'seggars,' such as are represented in fig. 6; these are made principally of a kind of fire-clay capable of resisting an intense heat; and so important are they, that the acquisition of the sort of clay fitted for the purpose has always been deemed a momentous point on the part of the manufacturer. The seggars are of various sizes, shapes, and depths, to suit the different pieces they are to contain. According to the size and shape of the articles, they are either enclosed one in each seggar, or several in each; but in the latter case precautions are taken that they should not adhere together, nor touch each other at more than two or three points: powdered flint is placed at the bottom of the seggars, and pieces of hard fire-clay are so placed within the seggar, that the articles may be supported with as little contact as possible one with another.

The piling of the seggars in the 'biscuit-kiln' is a singular arrangement. The whole interior is filled with them. The

top and bottom of each seggar (the former open and the latter closed) being flat, they may be piled one on another, so that each one forms a cover for the one underneath. As the heat cannot be perfectly equalized throughout the kiln, care is taken that the larger articles shall be exposed to a higher temperature than the smaller. Thus seggar is laid upon seggar, and pile after pile built up within the kiln, till the whole is filled.

Fig. 6.

Every aperture is then carefully closed—of which the main one is, of course, the door through which the men enter the kiln—and all is ready for the fires to be lighted beneath. The general appearance of the kiln while being filled is represented in fig. 7.

Forty hours is about the length of time during which they are thus exposed. The precise amount of 'firing' necessary is a delicate point, to be determined only by experience: it must be sufficient to expel all the moisture, and to convert the clay into a kind of semi-vitreous earth, but not beyond this point.

The baked articles are allowed to cool gradually before being drawn from the kiln; and when so drawn they have acquired the state which is called 'biscuit.' Every article shrinks considerably while in the kiln, and the weight is very materially lessened. The biscuit ware has a peculiarly delicate, soft, and white appearance, presenting many points of striking difference compared with its unbaked state. Every article, as taken out of the seggar, is nicely cleaned, to remove all symptoms of flint-dust, &c.; and it is then ready for the process of 'glazing,' by which the dead and unpolished surface of the biscuit is converted into a beautiful glassy surface.

One of the most important steps in the progress of the porcelain manufacture, has been the discovery of substances fitted to impart this 'glaze' to porcelain. Any of the substances which will make glass, will afford a glaze to pottery; and these substances comprise various alkalies, various oxides of metals, and flint in a variety of forms: but what is the best combination to form a glaze for the more delicate kinds of porcelain, is a question which has occupied much attention, not only among manufacturers, but among chemists also. In the commonest kinds of earthenware or pottery, the cheapest ingredients are those most resorted to; but in costly porcelain a totally different system is pursued, the excellence of the material being a much more important matter than the smallness of the price. We believe that in this, as in the choice of clays for making the porcelain, each large establishment has a recipe of its own, derived from the experience of the proprietors.

The pieces of 'baked' or 'fired' porcelain being brought into the 'dipping' room, a workman takes them up one by one, holds them in such a manner that there shall be the smallest amount of contact between them and his fingers, and dips them into a trough of glaze. By one of those manipulations which are peculiar to most occupations, he turns the vessel about, on removing it from the glaze, in such a manner that, while every part shall be coated, none shall have any superabundance but what may easily be drained off. The vessels are put down out of his hand, one by one, on a board, which is thence carried to the 'glaze-kiln placing-room.' In this latter room they are piled up in seggars, nearly in the same way as before, but with certain modifications, to suit the peculiarity of the circumstances.

The glaze-kilns, like the biscuit-kilns, are each heated by eight fires, and are each filled up with piles of seggars; but in the glaze-kilns the slight opening between the several seggars of each pile is stopped with clay, to prevent more effectually the entrance of smoke and flame into the seggar. The heat for vitrifying the glaze is much less intense than for biscuit-firing, and is continued for a much smaller number of hours. The operation consists in driving off the watery parts of the glaze, and melting the vitreous part, which, in a vitreous state, combines firmly with the biscuit. Where we find, in the cheaper articles of manufacture, the glaze to become discoloured,

Fig. 7.

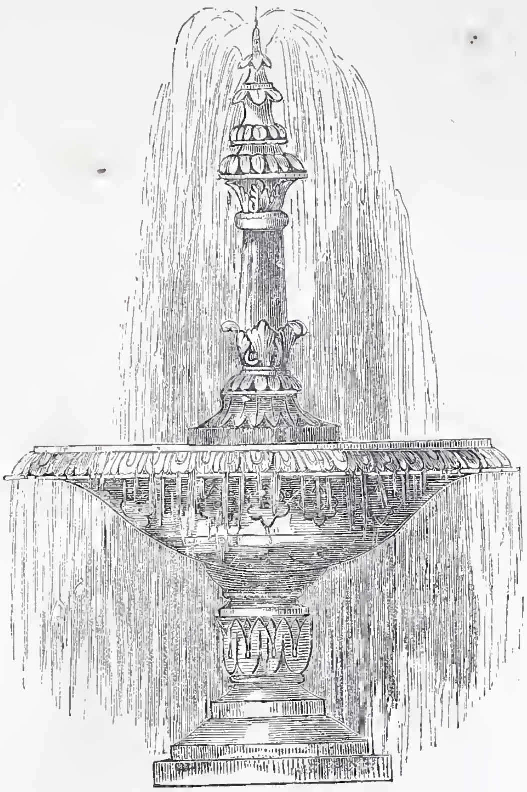
or the ware discoloured under the glaze, or the glaze intersected by myriads of minute cracks, this always indicates either that a bad choice of ingredients was made, or that the management of the glaze-kiln was injudicious; and this is one of the many points in which first-rate porcelain shows its excellence.

We have now brought the porcelain to what might be deemed a finished state, so far as regards the actual service demanded from it; but it is very rarely that such porcelain as we are now considering, leaves the hands of the manufacturer in this state; it is nearly always decorated either with painting or gilding, or both, before it passes into the hands of the customer. We follow it, therefore, to the 'painting-room,' where artists, seated

before a range of windows, apply, with a camel-hair pencil, mineral and oil colours to the surface of the porcelain.

In China, this branch of manufacture is so subdivided, that

Fig. 8.



one man paints blue, another red, another yellow, &c., so that each article goes through a great number of hands during the process of painting. But in England, the subdivision is more rational. One man takes flowers, another foliage, a third animals, a fourth landscape, a fifth figures, a sixth heraldic bearings, and so forth; confining themselves mainly to that which their taste and studies have enabled them to effect artistically. Each painter holds the piece of porcelain against a projecting part of his table, so as to retain it firmly; or else, if a circular ornament is to go round it, he rests it on a support which may enable it to rotate with facility. The colours employed in this process are chiefly oxides of various metals, worked up to a liquid state with spirits of tar and of turpentine, and amber oil. Those ornaments which are subsequently to present the brilliant golden appearance so familiar to us on the better kinds of porcelain, are effected by a preparation of refined gold mixed up with some of the liquids just mentioned into a dark-brown colour, which has no semblance to a golden hue until after it has been burned in a kiln.

Some of the articles of porcelain have a white or unpainted ground, decorated with coloured ornaments; while others are painted over the whole surface with a ground-colour, the laying on of which is the work of a particular set of painters, who show great art in the uniform tinting produced. Not only are vessels for table service thus painted, but the side-slabs for fire places, and a large variety of decorative furniture, are now made in porcelain, and then subjected to the taste and skill of the painter. This is one of the branches of the porcelain manufacture, in which the English have made very rapid progress within the last few years.

Conveniently placed with respect to the painting-room are the 'enamel-kilns,' in which the painted articles are exposed to a heat sufficient to make the colours adhere to the porcelain. These kilns are a kind of arched oven, having a door at one end, and gratings within on which the articles are placed. The most scrupulous care and delicacy are displayed in managing these kilns, as to the temperature and length of exposure. Sometimes the painter requires to partially heat the porcelain two or three times during the process of painting, to ascertain the effect of his colours, and to combine them well with the porcelain. Indeed, the care required in this process is very little less than in the exquisite one of enamel-painting.

We next follow the costly results of all the preceding labours to the 'burnishing-room,' a large apartment occupied by women and girls employed in burnishing those parts which have been gilt in the painting-room. The tools used for the purpose, called 'burnishers,' are bloodstones, firm hematite iron, and

Fig. 9.

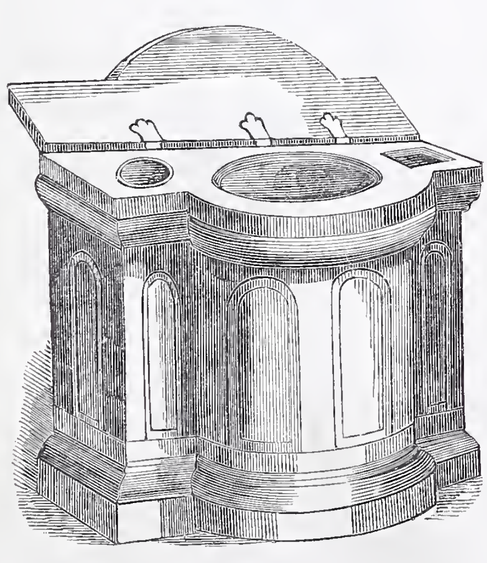


Fig. 10.

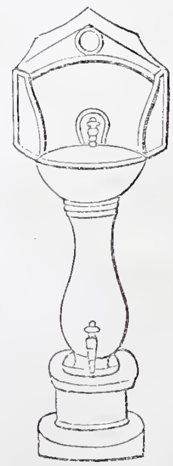
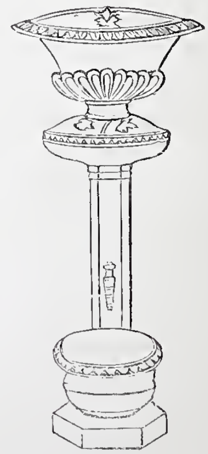


Fig. 11.



agates fitted into handles. The gold is first scoured with fine wetted sand, which tests the extent of the firing; if not sufficient, the gold will not adhere; and if in excess, the brilliancy will have been destroyed. In the first case, the ware has to be passed through the kilns again without further labour; but, in the latter, it has to be thoroughly regilt. After

'sanding,' the burnishers are applied very briskly, and immediately produce a polish, which is increased in brilliancy by repeated action. A cloth dipped in the solution of whiting is occasionally used to clear the surface. Each workwoman is seated at a bench with her face towards a window, holding the porcelain in the left hand, and the burnisher in her right, with which she rubs the gilded parts until they are brought to a brilliant gloss.

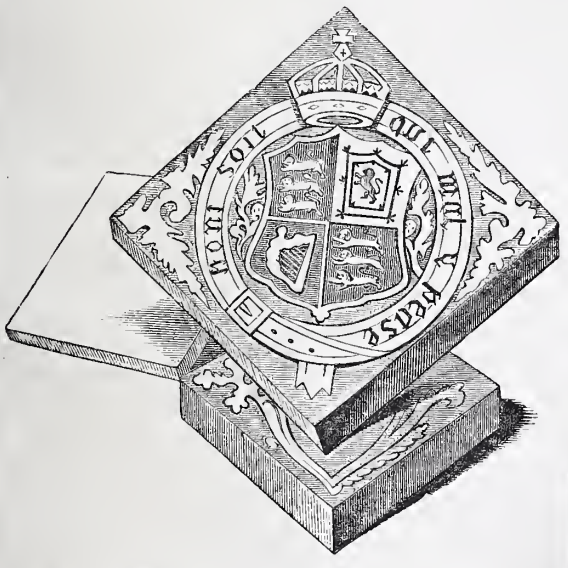
An entirely new application of pottery is shown in the lawn fountain, white and gold, playing, fig. 8, and also in the sanitary vessels, &c., figs. 9, 10, 11, consisting of fountain basins, closets, and other articles. Both of these are the production of Messrs. John Ridgway & Co., of the Staffordshire Potteries.

TESSELLATED TILES.

We must here say a few words respecting a branch of manufacture which promises to be much extended in England, viz., *tessellated tiles* for pavements, &c. Whoever has seen the Temple Church since its renovation several years ago, will have noticed the beautiful pavement which it displays, formed of a vast number of rectangular tiles about six inches square, glazed on the upper surface.

The tessellated tiles are formed of two differently coloured clays, one imbedded in the other, and disposed so as to form an ornamental device. The tile is first made in clay of one colour, with a depression afterwards to be filled with clay of the other colour, and this depression is formed by the aid of a mould. In the first place, the modeller models in stiff clay an exact representation of one of the tiles, about an inch thick, cutting out to the depth of about a quarter of an inch the depression which constitutes the device. When this is properly dried, a mould is made from it in plaster of Paris, and from this mould all the tiles are produced one by one. The ground-colour of the tile is frequently a brownish clay, with a yellow device; but this may be varied at pleasure. Let the colour be what it may, however, the first clay is mixed up very thick, and pressed into the mould by the aid of the press seen in the cut. On leaving

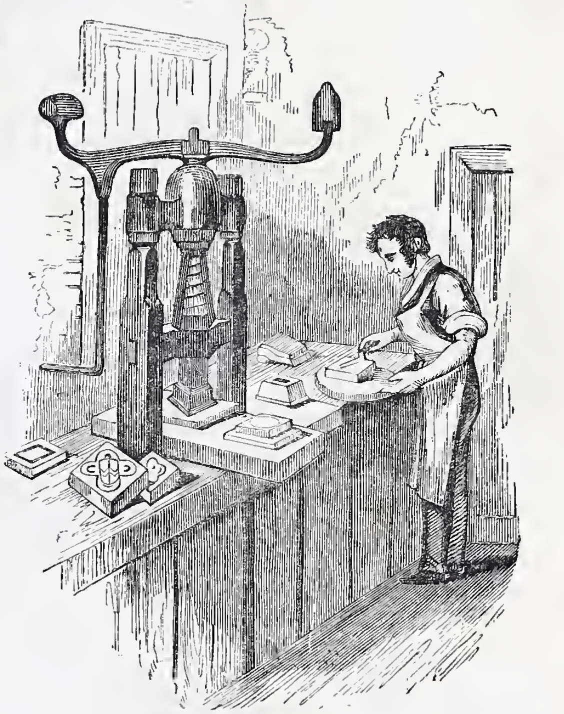
Fig. 12.



the press, it presents the form of a damp, heavy, unicoloured square tile of clay, with an ornamental device formed by a depression below the common level of the surface.

The second coloured clay, so far from being made stiff like the first, has a consistence somewhat resembling that of honey; and herein lies one of the niceties of manufacture, for it is necessary to choose clays which will contract equally in baking, although of different consistence when used. The tile being laid on a bench, the workman plasters the honey-like clay on it, until he has completely filled the depressed device, using a kind of knife or trowel in this process. The tile, in this state, is then allowed to dry very gradually for the long period of eight weeks, to accommodate the shrinking of the clays to their peculiar natures. After this, each tile is scraped on the surface with an edge-tool, till the superfluous portion of the second clay is removed, and the two clays become properly visible, one forming the ground and the other the device. In this state the tiles are put into a 'biscuit-kiln,' where they are baked in a manner nearly resembling the baking of porcelain, but with especial reference, as to time and temperature, to the quality of the clays. From the biscuit-kiln they are transferred to the 'dipping-room,' where they are coated on the upper surface with liquid glaze by means of a brush. Lastly, an exposure to the heat of the 'glaze-kiln' for a period of twenty-

Fig. 13.



four or thirty hours causes the glaze to combine with the clay, and the tiles are then finished.

In the manufacture of what are called *dry tiles*, on the principle patented by Mr. Prosser, the clay powder, as it comes from the mill, is placed in slabs of plaster of Paris, slightly damped. It is then sifted through a series of fine sieves, and afterwards subjected to enormous pressure by means of a screw-press, which makes the particles of powder consolidate into firm slabs or tiles. At the lower extremity of the screw of the press is fixed a steel plate of the size and pattern of the intended tile: this fits into the upper part of a steel box of the same dimensions, the bottom surface of the box being ribbed, that the tile receiving the impression may adhere more strongly to the mortar in which it is afterwards embedded. The pressure applied is about 400 tons, by which a thickness of three inches of powder is compressed into a tile one inch thick, with sharp edges and a beautiful polished surface. At the same time, the mould may be so formed that any desired impression may be communicated to the surface. New improvements have been made in this manufacture within the last two or three years; steam-power is now employed, so that the pressure on each tile is mathematically the same. Buttons for shirt studs, tesseræ for mosaic work, table-tops, furniture panels, and other beautiful articles, are thus produced with amazing rapidity. By one machine, 5000 tiles may be made in 24 hours. The articles, when taken from the press, are removed to a hot room for a week or two, where they are ornamented, glazed, and fired.

HYDROMETRICAL OBSERVATIONS.

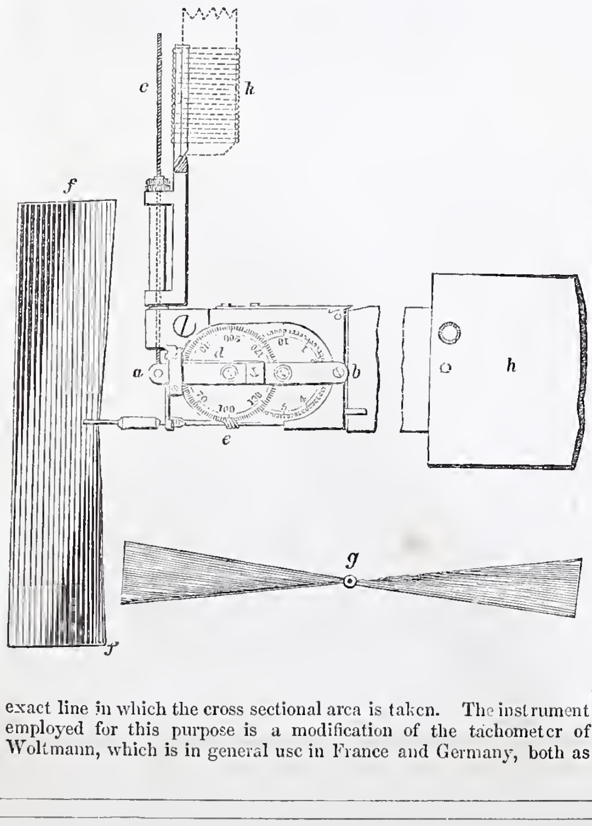
BY DAVID STEVENSON, ESQ., CIVIL ENGINEER.

Velocities of Currents.—For the purpose of ascertaining the surface velocities of currents, various methods may be employed.

The most common, but by no means the most satisfactory mode of proceeding, is to throw into the water a float composed of some small body (whose specific gravity is merely great enough to sink it to a level with the surface), at a point about 30 or 40 feet above the line of section, so as to insure its acquiring the full velocity of the current before it reaches the cord. An observer, stationed at the cord, notes exactly the moment at which the float passes, and follows it down the stream till he reaches the line of two poles, which have been fixed in reference to the observations, when he again notes the exact moment of its transit at the lower station. The elapsed time between the two transits is then noted in the book, along with the distance between the two places of observation, which, owing to the irregularity of most rivers, with regard to width, depth, and velocity, can seldom be got to exceed 100 feet. This operation has, of course, to be repeated for every compartment of the cross section.

Certain disadvantages attend this method, which render it not generally applicable. For example, it is only adapted to rivers of limited breadth, owing to the impossibility of an observer being able to discover with sufficient accuracy when the float passes the station lines, if it be viewed from a distance, as from the bank of a broad river. There are, however, greater objections than this, which, when pointed out, will be sufficiently obvious to every one. In any part of the river passed over by the floats, the slightest irregularity of the bottom produces a disturbance in the motion of the stream, and alters the velocity of the current, so that the result indicated by the elapsed time is more or less vitiated; and the mean velocity deduced from such data is not, in almost any case, that which exists at the line of cross section. It is also impossible, by this method, to obtain a sufficient number of distinct and independent observations, applicable to each division of the stream; as the eddies and irregularities of the current, which exist in all rivers, generally cause the lines passed over by the floats to cross and interfere with each other, in such a manner as to destroy all connection between any given series of observations, and the several compartments of the river, whose mean velocity they were intended to ascertain.

The superiority of the method which I am about to describe, consists in ascertaining the velocity of each portion of the stream, in the



exact line in which the cross sectional area is taken. The instrument employed for this purpose is a modification of the tachometer of Woltmann, which is in general use in France and Germany, both as an anemometer and a hydrometer, being made of the degree of delicacy suited to the purpose to which it is to be applied. In this instrument, the velocity is measured by the current impinging on a vane and causing it to revolve, the number of revolutions made by the vane being registered on an index, which is acted on by a set of toothed wheels.

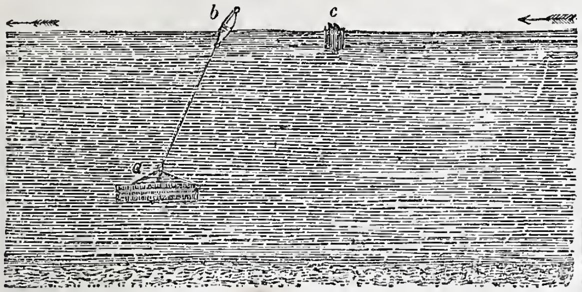
The construction of this beautiful instrument, and the manner in which it acts, will be best described by a reference to the accompanying figure—which is taken from a tachometer or stream-gauge made by Mr. Robinson, optician, London, and is drawn to a scale of one-third of the full size. In this view, *f f* represents what may be termed the driving vane, which is acted on by the stream, and of which *g* is a plan. The plane of this vane is twisted, as represented by the dark shading in the cut, so as to present, not a knife-edge, but an oblique face to the action of the current, which, by impinging on it, causes it to revolve exactly in the same way that the wind propels the sails of a wind-mill. On the spindle or shaft of this vane an endless screw is fixed at *e*, which works in the teeth of the first registering wheel, and causes it to revolve when the vane is in motion and the screw in gear. Letters *a* and *b* represent a bar of brass, to which the pivots on which the registering wheels revolve are attached. This bar is moveable on a joint at *b*; and at the point, *a*, a cord, *a c*, is fixed, by pulling which, the bar and wheels can be raised, and on releasing it, they are again depressed by a spring at *d*. When the bar is raised, the teeth of the wheel are taken out of gear with the endless screw, and the vane is then left at liberty to revolve, the number of its revolutions being unregistered; but when the cord is released, the spring forces down the wheels, and immediately puts the registering train into gear, in which state it is represented in the cut. Letter *h* is a stationary vane (which is shown broken off, but measures about nine inches in length), for keeping the plane in which the driving vane revolves, at right angles to the direction of the current, and *k* is the end of a wooden rod to which the tachometer is attached when used. The different parts of the instrument itself are made of brass.

The moveable bar for the registering wheels, and the application of the cord and spring which have been described, afford the means of observing with great accuracy, in the following manner:—The instrument having been adjusted by setting the registering wheels at zero, or noting in the field-book the figure at which they stand, the cord is pulled tight, so as to raise them out of gear, and the instrument is then immersed in the water. The vane immediately begins to revolve from the action of the current, and is permitted to move freely round until it has attained the full velocity due to the stream. When this is supposed to be the case, a signal is given by the person who observes the time, and the registering wheels are at that moment thrown into gear by letting the cord slip. At the end of a minute another signal is given, when the cord is again drawn, and the wheels taken out of gear, and on raising the instrument from the water, the number of revolutions in the elapsed time is read off. This operation being completed in the centre of each division of the cord, the number of revolutions due to the velocity at each part of the very line where the cross section is taken, is at once obtained.

Before using the tachometer, it is obvious that the value of a revolution of the vane must be ascertained; and although this is done by the manufacturers, it is proper that the scale of each instrument should be determined by the person who uses it, and that it be tested, if the instrument has been out of use for some time, before being again employed in making observations. A scale sufficiently accurate for most hydrometrical purposes (though not for the instrument when used as an anemometer), may be obtained by applying it to some regular channel, such as a mill-lead formed of masonry, timber, or iron, where the velocity is nearly the same throughout, and noting the number of revolutions performed during the passage of a float over a given number of feet, measured on the bank. In this way it was found, by the mean of 62 observations, that each revolution of the vane in the instrument, of which a drawing has been given, indicated the passage of the water over 46 inches. The number of revolutions, at several parts of the stream, was ascertained to be the same in equal times, at both the commencement and the end of the experiments. This number, therefore, becomes, in the instrument alluded to, a constant multiplier of the number of revolutions indicated by the vane; and hence, the number of feet passed over by the water in the given interval of time is ascertained.

The direction of the under current, which it is sometimes interesting to know, cannot, however, be obtained by means of the tachometer; and I shall describe a plan for obtaining an approximation to both the velocity and direction of under currents, which is of easy application, and may be useful to those employed in engineering investigations. The plan to which I allude was devised and used at the Cromarty Frith in 1837, by Mr. Alan

Stevenson, who discovered, by means of the instrument he employed, the interesting fact, that, at the depth of 50 feet, the velocity of the current, at both flood and ebb, is in certain places of the Frith nearly double that at the surface. This instrument, which of course merely gave an approximate result, consisted (as shown in the accompanying cut, at letter *a*,) of a flat plate



of sheet iron, measuring 12 by 18 inches, having a vane made of the same material, and measuring 4 feet in length, fixed at right angles to the centre of it. The lower edges of the plate and vane were loaded with bars of iron, for the purpose of causing the instrument to sink to the requisite depth; and it was so slung as to preserve the surface of the plate in a vertical plane. This apparatus was secured by a cord of sufficient length to sink it to the required depth, and the whole was attached to a tin buoy, letter *b*, which floated on the surface, its form being such as to produce little resistance to its passage through the water. The buoy served not only to preserve the vane plate at the same depth, but also indicated its progress through the water in a very satisfactory and often interesting manner.

The plate, sunk at the depth of 50 feet, when acted upon by the force of a strong under current, was hurried along, carrying the buoy, which floated on the surface, along with it, a circumstance which was ascertained by the buoy passing the floats thrown out on the water as gauges of the velocity and direction of the upper current, one of which is shown at *c*. The only precaution to be observed in making such observations is, to exclude that part of the commencement of the buoy's course—which is more rapid than it ought to be, owing to the effort made by it to overtake the plate—which, being sunk first, has been influenced by the velocity of the under current before the buoy has been launched. It is evident that, by means of this simple apparatus, we can approximate to the direction as well as to the velocity of under currents; but it must be kept in view that, in either case, there are several deranging influences in operation, which tend to render the results obtained merely rude approximations to the truth.

The direction of surface currents may be easily observed by means of a string of cork floats. Any change in the direction of the line traced by the floats, is noted by observations made with the surveying compass or the sextant, by an observer stationed in a boat, which is rowed alongside of the line marked out.

The last hydrometrical topic which shall engage our attention is, the method of obtaining specimens of water at different depths, with a view to ascertain its qualities, in regard to the proportion of sea salt which it contains, or the quantity of sand or mud held in mechanical suspension.

The first observations made on this subject, so far as I am aware, were those instituted by my father on the River Dee, in Aberdeenshire, in the summer of the year 1812, when engaged in surveying that river in reference to a salmon fishing case.* "He observed, in the course of his survey, that the current of the river continued to flow toward the sea with as much apparent velocity during flood as during ebb tide, while the surface of the river rose and fell in a regular manner with the waters of the ocean. He was led from these observations to inquire more particularly into this phenomenon, and he accordingly had an apparatus prepared, under his directions, at Aberdeen, which, in the most satisfactory manner, showed the existence of two distinct layers or strata of water; the lower stratum consisting of salt or sea water, and the upper one of the fresh water of the river, which, from its specific gravity being less, floated on the top during the whole of flood as well as ebb tide. The apparatus consisted of a bottle or glass jar, the mouth of which measured about $2\frac{1}{2}$ inches in diameter, and was carefully stopped with a wooden plug, and luted with wax: a hole, about half an inch in diameter, was then bored in the plug, and to this an iron peg was fitted. To prevent accident in the event of the jar touching the bottom, it was coated with flannel. The jar so prepared was fixed to a spar of timber about twenty feet in length, which was graduated to feet and inches, for the conveniency of readily ascertaining the depths to which the instrument was plunged, and from which the water was brought up. A small cord was attached to the iron pin for the purpose of drawing it at pleasure for the admission of the water. When an experiment was made, the bottle was plunged into the water: by drawing the cord at any depth within the range of the rod to which it was attached, the iron peg was lifted or drawn, and the bottle was by this means filled with water, of the quality at the depth to which it was plunged. The peg was again dropped into its place, and the apparatus raised to the surface, containing a specimen of water. In this manner the reporter ascertained that the salt or tidal water of the ocean flowed up the channel of the River Dee, and also up Footdee and Torryburn, in a distinct stratum next the bottom and under the fresh water of the river, which, owing to the specific gravity being less, floated upon it, continuing perfectly fresh, and flowing in its usual course towards the sea,—the only change discoverable being in its level, which was raised by the salt water forcing its way under it. The tidal water so forced up continued salt, and when the specific gravities of specimens from the bottom, obtained in the manner described, were tried, and compared with those taken at the surface, by means of the common hydrometer of the brewer (the only instrument to which the reporter had access at the time), the lower stratum when compared with that at the surface was always found to possess the greater degree of specific gravity due to salt over fresh water."

The appearance of the fresh water floating on the surface of the sea is no doubt familiar to most persons. It occurs at the mouths of many of our rivers, and is most apparent when they are in flood, from the brown tinge given to the water, which is easily discoverable for many miles at sea. The great American rivers furnish many remarkable instances, particularly La Plata and the Amazons. On this subject, the following passage from the work of Father Manuel Rodriguez, a Spanish Jesuit, is interesting; and its correctness, as regards the extent to which the influence of the river is felt, has since been corroborated by the investigations of Colonel Sabine.* "This river," says Rodriguez, in speaking of the Amazons, "is like a tree; its roots enter as far into the sea as into the land, so that it communicates to it a flavour; so that at 80 leagues within the sea, its waters are seen and taste sweet, and in a semicircle of 100 leagues in circumference, they form a gulf not in the least brackish, so that the sailors call it the fresh sea."

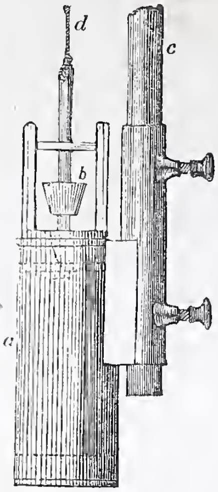
The instruments now used for obtaining water from different depths are more perfect in their construction, than that already alluded to as having been used at the Dee, which, as has been seen, was made for a temporary purpose. Instruments of various constructions have of late been tried for experimenting on this subject; and as I am not aware that any work on marine surveying, or on surveying instruments, contains a description of such an apparatus (to which I have applied the name of the *hydrophore*, from ὕδωρ, *water*, and φορέω, *to carry*), the following account of two modifications of it, both of which I have been in the habit of using, may perhaps be instructive.

The following figure represents a hydrophore used for procuring specimens of water from moderate depths, drawn on a scale of one-tenth of the full size. It consists of a tight tin cylinder, letter *a*, having a conical valve in its top *b*, which is represented in the diagram as being raised for the admission of water. The valve is fixed *dead*, or immovable, on a spindle working in guides, the one resting between two uprights of brass above the cylinder, and the other in its interior, as shown in faintly dotted lines. The valve-rod is by this means caused to move in a truly vertical line, and the valve attached to it consequently

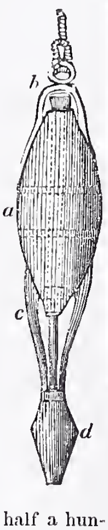
* Report to the Earl of Aberdeen and the other Proprietors of the "Raik" and "Stell" Fishings of the River Dee, at Aberdeen, by Robert Stevenson, Civil Engineer. Edinburgh, February, 1813.

* An Account of Experiments to Determine the Figure of the Earth, as well as on various other subjects of Philosophical Inquiry, by Edward Sabine. London, 1825, pp. 445.

fits the hole in the top of the cylinder with greater accuracy than if its motion was undirected. A graduated pole, *c*, which in the diagram is shown broken off, is attached to the instrument, its end being inserted in the small tin cylinder at the side of the large valve or water cylinder, and then fixed by the clamp screws shown in the diagram; the bottom of the water cylinder may be loaded with lead to any extent required. The spindle carrying the valve has an eye in its upper extremity to which a cord is attached for the purpose of opening the valve when the water is to be admitted, and on releasing the cord, it again closes by its own weight. When the hydrophore is to be used, the cylinder is lowered to the required depth by the pole which is fixed to its side; or if the depth be greater than the range of the pole, it is loaded with weights, and let down by means of a rope so attached as to keep it in a vertical position. Care must be taken while lowering or raising it, that the small cord by which the valve is opened be allowed to hang perfectly free and slack. When the cylinder has been lowered as far as is required, the small cord is pulled, and the vessel is immediately filled with the water which is to be found at that depth. The cord being then thrown slack, the valve descends and closes the opening. The instrument is then slowly raised to the surface by means of the rod or rope, as the case may be, care being taken to preserve it in a vertical position. This apparatus is only applicable to limited depths, but will generally be found to answer all the purposes of the civil engineer.



The form of hydrophore, represented in this figure, is used in deep water, to which the small one is inapplicable. It consists of an egg-shaped vessel, letter *a*, made of thick lead, to give the apparatus weight, having two valves *b* and *c*, one in the top and another in the bottom, both opening upward; these valves (which are represented as open in the diagram) are, to ensure more perfect fitting, fixed on separate spindles, which work in guides, in the same manner as in the instrument shown in the last figure. The valves, however, in that which I am now describing, are not opened by means of a cord, but by the impact of the projecting part *d*, of the lower spindle on the bottom, when the hydrophore is sunk to that depth. By this means, the lower valve is forced upwards, and the upper spindle (the lower extremity of which is made nearly to touch the upper extremity of the lower one when the valves are shut) is at the same instant forced up, carrying along with it the upper valve which allows the air to escape, and the water rushing in fills the vessel. On raising the instrument from the bottom, both valves again shut by their own weight and that of the mass of lead *d*, which forms part of the lower spindle. The mode of using this hydrophore is sufficiently obvious. This instrument weighs about half a hundred weight, and has been easily used in from 30 to 40 fathoms' water in making engineering surveys, and could, no doubt, be employed for much greater depths if necessary.



In all these experiments, the water being emptied into bottles is corked up, and labelled with certain numbers, which should be entered in a book containing remarks as to the place of observation, time of tide, and such other particulars as, from the nature of the inquiry, seem to deserve notice; and the water thus preserved may be subjected to analysis, produced in evidence, or employed in any other way required by the circumstances of the case.

The marine productions of an estuary, such as the fish, shells, and plants which occur in it, occasionally affect questions regarding which an engineer may be consulted; but as it is not my present intention, as stated at the beginning of this chapter, to enter into the nature of the questions in which these investigations are required, or the manner in which they bear upon them, it is not considered necessary, in mentioning these productions, to do more than simply direct attention to the subject. —*Treatise on the Application of Marine Surveying and Hydrometry to the Practice of Civil Engineering.*

ON THE PROBABLE MODE OF CONSTRUCTING THE PYRAMIDS OF EGYPT.

BY HENRY PERIGAL, ESQ.

For two or three thousand years, or more, it has been a matter of wonder, and a favourite subject of surmise and inquiry, how the Egyptians contrived to elevate to their places the enormous masses of stone of which the Pyramids are constructed; such being the magnitude of these structures and the supposed difficulties surmounted in their erection, that the great Pyramid was designated one of the "seven wonders of the world." What kind of engines were employed (if any were used), or what expedients were adopted to raise the ponderous stones, has continued a mystery to the present time; although various methods have been suggested, more or less practicable, not one of these conjectures has been considered a satisfactory solution of the problem which has baffled the learned and ingenious for so many ages.

Chronologers assert that the Great Pyramid of Gizeh is from 4000 to 5000 years old. Herodotus, who visited Egypt about 2200 years ago, gives the following account of its erection, as described by the priests, who then had charge of the Pyramids:—

"They told me likewise that Cheops, who succeeded Rhampsinitus, oppressed the Egyptians with hard labour; appointing some to receive the stones that were dug out of the quarries in the Arabian mountains and convey them down to the Nile; and when they had been transported in vessels to the other side of that river, he appointed others to receive them, and to drag them to the mountain called the Libyan. Ten years were spent in constructing the causeway along which they drew the stones. Twenty years spent on the Pyramid, which is quadrilateral, every face containing eight plethra* in length, and the same measure in height. All the stones† are 30 feet long, well polished, and joined together with the greatest exactness. This Pyramid was built in successive layers in the form of steps, like an altar. When they had commenced in that manner they superposed other stones by means of machines consisting of short pieces of wood, raising them first from the ground in the first range; when the stone arrived there it was put on another machine, which rested on the first step, from which it was raised to the second, and so on, for the engines thus employed were equal in number to the several ranges of stones; or perhaps there was but one engine, which, being easily managed, might be removed as often as they deposited a stone; for I must mention both ways, as related to me. The summit was first completed,‡ and the rest in succession, so that the last of all finished were the lowermost parts nearest the ground." (Herodotus, b. ii. ch. 124 and 125.)

Although the stones of the great Pyramid are not all 30 feet long, as Herodotus asserts, yet some of them are more than 40 feet long; and in the middle Pyramid of Abousëir, the roof of one of the apartments is formed by three tiers of blocks, each block $48\frac{1}{2}$ feet in length. In the ruins at Balbec are "three stones elevated nearly 20 feet from the ground, each measuring 70 feet in length by 15 in width, while in the quarries, about a mile from the city, there still remains one enormous block, smoothed, planed, and ready for removal; it measures 70 feet in length, 14 feet in height, and is 17 feet in thickness at one end and $13\frac{2}{3}$ feet at the other, being the same shape, but larger than those in the wall." Mr Wood computed its weight at 2,270,000 lbs., or 1135 tons!

There appears to be no evidence to prove that the architects of the Pyramids were acquainted with any contrivances or combinations equivalent to what would be called machines or engines, according to the modern acceptation of the words; on the contrary, it seems much more probable that their gigantic undertakings were accomplished by some very simple means; which simplicity (leading to the notion that the means were self-evident) was perhaps the very reason that no record was kept, or transmitted to posterity, of their mode of operation. With this conviction, on the

* 808 feet.
† Meaning, probably, the casing-stones, or polished stones, with which it was faced.
‡ *Faced* with polished stones.

assumption that the statement of Herodotus might be founded on fact, I endeavoured to discover in what manner such prodigious blocks *could* have been elevated, from step to step, *merely by the aid of short pieces of wood*, when the idea occurred to me that they *might* have been so raised by some such system as the following.

Each block of stone, shaped and prepared for use before it left the quarry, was conveyed across the Nile (advantage being taken of the periodical inundations) on rafts, or other appropriate vessels, to the causeway described by Herodotus; along which it was dragged on rollers, or on sledges if the stone was smoothed or polished, by the labour of men (or of cattle), to a convenient locality adjoining the Pyramid, where it remained till wanted; thence it was conducted to the first step of the Pyramid on rollers. To get the rollers underneath, wedges were used, if it lay on the hard rock; otherwise the earth was removed from beneath one half of the stone, the director or superintendent having placed himself upon the further end to prevent it from tilting over too soon.

Next, the director having walked on the top to the other end, the stone (overbalanced by the leverage of his weight) tilted into the hollow ground, when rollers were placed under the other half of it.

The director having walked back again, the stone was tilted on to the rollers, and conveyed to its destination at the foot of the Pyramid, where, perhaps, it was transferred in a similar way to larger rollers.

Then commenced the lifting process. All but one roller being removed, that one being as nearly as possible under the centre of gravity, the stone was tilted as before, while flat boards or planks were placed beneath; and upon these boards another much narrower to act as a fulcrum, all being about the same length, proportioned to the width of the stone.

The director having walked to the other end, the stone was tilted on to the boards, and similar planks were piled beneath alongside or parallel to the others, but a degree higher or more in number; and upon them also a narrow fulcrum-slip, upon which the stone was then tilted.

The director having repeatedly walked backwards and forwards, tilting each end of the stone alternately, and additional boards having been introduced every time, the stone gradually rose to the required height, rather exceeding that of the next step, when rollers were placed on the boards, and the stone was transferred to similar planks placed in readiness on the next step of the Pyramid.

The same process was then renewed, and continued from step to step till the structure arrived at its destined locality.

Should any of the stones have been short, and consequently have afforded insufficient leverage for one man's weight to tilt them, he might have carried the load; or planks might have been made fast at the top, so as to project beyond the ends of the stone, for him to walk along; or two or more men might have been employed in traversing the stone; or various other expedients might, obviously, have been adopted to tilt the stone. The wood probably underwent some preparatory process, by which it was condensed and its elasticity destroyed, perhaps by being subjected to very heavy pressure when sodden by boiling water.

Thus "the properties of the lever and of the centre of gravity were brought into co-operation, so that the *weight to be lifted was itself the principal element of the lifting power*." Figuratively speaking, the stone was made to raise itself by means of its own weight.

In this manner, with the aid of a few dozen planks, a couple of men (one traversing the stone while the other arranged the planks) might have conducted to the top of the great Pyramid the largest stone used in its construction; thus corroborating the assertion of the Egyptian priests, as stated by Herodotus, that the "stones were raised from step to step by the aid of short pieces of wood; which, being portable and easily managed, might be removed or transferred as often as they deposited a stone; or different sets might have been employed for every range of steps." By this simple process, also, a few men might have raised Stonehenge in a single night, if the requisite stones were provided and placed in readiness near the spot, without any previous or subsequent indication of the means by which it was effected.

In conclusion, I may add, that in looking over a good many works on Egypt and its antiquities, I have not succeeded in meeting with any direct proof that this system was the very method, or one of the methods, actually practised by the Egyptians; but perhaps the following quotation may be interpreted into something like presumptive evidence of its probability, as the fracture of the obelisk *in the middle*, as there described, is an accident very likely to have occurred in the attempt to move the shaft by such a process, if the stone happened to be brittle, or its breadth and thickness too small for its length. "In one of the quarries at E'Sooan (Syene) is a granite obelisk, which, having been *broken in the centre* after it was finished, was left in the exact spot where it had been separated from the rock. The depth of the quarry is so small, and the entrance to it so narrow, that it was impossible for them to turn the stone in order to remove it by that opening; it is therefore evident that they must have lifted it out of the hollow in which it must have been cut, as was the case with all the other shafts previously hewn in the same quarry. Such instances as these suffice to prove the wonderful mechanical knowledge of the Egyptians; and we may question whether, with the ingenuity and science of the present day, our engineers are capable of raising weights with the same facility as that ancient people."*

With the latter opinion I cannot coincide; I am confident that some of our engineers could manage to construct a pyramid as large as that of Cheops, with as large stones, in a tenth part of the time, with a hundredth part of the number of workmen, if they were not limited in its cost.

LECTURES ON SCULPTURE.

BY SIR RICHARD WESTMACOTT.

LECTURE IV., OR CONCLUDING LECTURE.

THE POST-PHIDIAN ERA IN GREECE.—EXPRESSION.—THE ROMAN PERIOD.—DECLINE AND REVIVAL OF THE ARTS.

The example of the school of Phidias maintained its influence, and was followed in bright but varied succession through several ages; but that simplicity and vigour, that tranquil grandeur, the peculiar character of his style, cannot be considered to have been fully sustained for more than fifty or sixty years.

The art which succeeded was of a more voluptuous kind, and the decided forms of the former were often dissolved into the androgynous, or mixed character of the two sexes.

The first example of the union of the two styles may be seen in a female torso discovered in the ruins of the amphitheatre at Capua; the beauty and breadth in the head, the sweetness and, at the same time, dignity of its expression, are not surpassed by any work in sculpture known to exist. Throughout the body there is a truth in the imitation, and a grace in the flowing of the lines, which make us regret that so small a portion of so exquisite a work should have been recovered. We probably contemplate in this fragment the actual forms, with very little variation, of a Grecian woman. The marble has all the appearance of having been worked from a cast from nature.

As the revolution in art, by the dismissal or rejection of symbolical or rather prescribed forms, was effected by no violation of the established principles of the art itself, as it was practised in the schools of Argos, Sicyon, or Corinth, the general sentiment became easily reconciled to the change, and it was soon extended, not only over the mother country, but also throughout the colonies of Greece.

The sublimity which Phidias had imparted to his works,—the diligence, precision, and grace which characterized those of Polycletus,—and the executive skill of Agoraeritus, Alcamenes, and Ctesilas, preserved their force through all the vicissitudes of art; but their value in combination has, perhaps, in no instance been more beautifully illustrated than in the two statues of the Venus of Capua, at Naples, and that known as the Venus of Melos, now in the Louvre. The received opinion that it was the custom of that, and certainly of preceding ages, to clothe the statues of females, (even those of Venus, which goddess there can be no doubt these works personify,) may be considered an objection to attributing these statues to this period of art. It is, however, the only argument which can be adduced against it; for, from a careful examination of them, and comparison with the draped groups from the pediment of the Parthenon, we find in both, but more particularly in the Venus of Melos, the same style of form and peculiarities in the naked parts, and precisely the same treatment and mode of execution in the drapery, while they offer, in their whole, examples of all the higher qualities of the art belonging to that time.

The Professor said, it was not his intention to extend his consideration of the elementary qualities of Art further than was necessary for the illustration of his remarks on the several works

* Manners and Customs of the Ancient Egyptians, by Sir S. G. Wilkinson F.R.S. vol. iii., p. 332.

to which he might have occasion to refer; but Expression being intimately connected with almost every object of this period, and as many works, either in the original or in ancient copies, remain to us in so perfect a state as to allow of our reasoning on their motives, he should offer, incidentally, any observations on this, or any other quality, which the subject might demand, rather than make them the subject of a distinct discourse

As every action of the body depends upon, or is influenced by, the mind, and as the great aim both of the sculptor and the painter is to endow his work with the passions and affections he himself conceives to be appropriate to his subject, and to communicate them and make them obvious to the spectator, the countenance and the gesture or action should necessarily be in perfect accordance or agreement. Of the attention the Greeks paid to this, and as an instance how forcibly they felt the necessity for its observance, no stronger example can perhaps be offered than the statue commonly called the Dying Gladiator. In the remarks which were offered in the first lecture of this course, on the qualities which were common to all works of the Greeks, as belonging to a class, this statue was particularly alluded to, and doubts were expressed as to the propriety of admitting it into the class of athletæ. The following are some of the reasons for excluding it:—This statue has been ascribed by some to Ctesilas, but upon what authority it is difficult to conjecture. The character of his works was elevation; and he is spoken of generally, but by Pliny more particularly, as being remarkable for adding nobleness to that which was already noble. Now this work, although inimitable both in its accordance throughout, and in its fidelity to nature, is evidently the representation of a man of low condition. This is expressed in the head and in the left hand, and more especially in the feet. In this statue there are none of the distinctive marks of a figure adapted to, or educated for, athletic exercises. There is neither compactness of form, nor decision of parts, such as we find even in our own prize-fighters, after the course of training necessary for their contests. That this work may have been of the time of Ctesilas is highly probable, as we have examples, though few indeed remaining, of works expressing, like this, individual nature, as in the Whetter, or Listening Slave, in the Tribune at Florence, in the well known statue of the Boy drawing the Thorn from his Foot, the Imploring Genius, at Berlin, and the fine fragment in the British Museum, of the Two Boys quarrelling over the Tali. But, admitting this statue to be of this age, it could not represent a gladiator; human sacrifices, it is true, were common at very remote ages, but these had been discontinued for many centuries, and gladiatorial exhibitions were first introduced into Greece by Antiochus Epiphanes, at a very late period, probably not earlier than one hundred years before Christ, and more than three hundred years after Ctesilas. Winckelmann has suggested that this statue may represent a dying herald; and, on the authority of Pausanias, has imagined it may be Antemocritus, the Athenian herald, who was killed by the Megareans—a violation of the laws of arms so strongly resented by the gods, that, says Pausanias, their city was never able to recover from it. That this event had been considered of no slight importance by the Greeks, is evident from their having erected a monument to the same herald on the road from Athens to Eleusis. It must be borne in mind that the accessories of the short sword and belt, and also the right arm of the statue alluded to, are restorations.

A very fine example of accordance of action with expression is afforded in the statue of Aristides, at Naples, in which the firm, uncompromising character of the head is not more expressive of mind than are the composed position of the arms and the attitude of the whole figure. In the same class of individual nature, and it is probably of the same period, may be classed the two statues of Philosophers, in the collection at Petworth. They have all the characteristics of fine art, and are also valuable specimens of the mode of conducting portrait sculpture.

Expression depending, as has been observed, on the mind, it becomes impossible to lay down any fixed rules for the guidance of the student. The principal features of particular passions may be defined, but their modifications and treatment must depend upon the degree of force required, and on the direction of the genius of the artist, whose mind, indeed, may be considered a kind of mirror, upon which the images of external objects are received, and from which they are reflected in his works.

In the sympathies which it excites, and in the examples which it affords of gradation of expression, no work offers a wider field for observation than the group of Niobe and her Children. This great work may be considered rather as the precursor than as immediately belonging to the school of Praxiteles. It appears that doubts were entertained even in the time of Pliny (who says that these statues adorned the Temple of Apollo Sosianus, at Rome), whether they were to be attributed to Scopas or Praxiteles. The passage in Pliny is short and rather ambiguous, and might lead at first sight to the supposition that Scopas and Praxiteles were considered contemporaries, whereas the former flourished nearly eighty years before the last named. The same subject had been treated by Phidias, and was one of those which adorned the throne of the Elean Jupiter. The statues referred to may more properly be ascribed to Scopas, from the character and simplicity of the draperies in several of the daughters, and from the markings in some of the eyelids, especially in the figure of Niobe herself, and which indicate a style more severe and vigorous than belongs to the sculpture of Praxiteles. Although these statues cannot, with respect to execution, be ranked in the first class, they must always, from their variety and expression, be considered as powerful efforts of the mind; and the balance of parts, and the character and sentiment appropriate to the subject, are so happily preserved throughout, that, as a whole, they fully deserve to be regarded as amongst the finest examples left us of ancient sculpture. In this assemblage there are no fewer than fourteen different objects under the influence of fear, and the effects of grief, expressed with all the circumstance and variety which Nature dictates. The profile of the face of Niobe is of the most sublime harmony; the forehead is small and well rounded, the eye well incased, of fine form and admirable expression; the eyebrow is gently arched, the line at the same time being rather sharply indicated along the bone, a distinction of treatment peculiarly suited to the severe style, opposed to the more graceful treatment of a latter age, which rounded the parts. The chin, and the whole contour of the lower jaw, is full and round. The mouth, which is gently opened, is of inexpressible sweetness; its breadth, from the dilatation of the nostrils, scarcely exceeds that of the nose, the fulness of the lips preserving an harmonious proportion with the lower part of the face and chin; the hair, bound by a fillet, falls in easy, but graceful, negligence over the shoulder; the arrangement, indeed, of the whole bust shows it to be of the best time of art; and as a model of beauty it may be considered of the purest form. It is impossible to regard this head without feeling pleasure from the harmonious assemblage of the parts, and without, at the same time, being moved with pity from the strong image of grief which it offers. The chest and breasts are full without being too much charged, an effect which was avoided by the Greeks, even in the forms of women of a more advanced age. The statue of the daughter clinging to the principal figure equally demands our attention. The forms chosen, and the beauty expressed, though distinct from that of the mother, are appropriate to the age of incipient womanhood, and appear, in conjunction with the mother, in form and beauty so perfectly in accordance, as to be only so many modifications of unity itself. Fear is strongly expressed in her countenance, but it is the fear of innocence and of that expression of quickness and sudden impulse with which a girl would fly, on apprehension of danger, for refuge to a mother. She is represented of an age to admit the tender developments of form, the better to express which the sculptor has judiciously draped her only to the hips, with the simple *chiton*, which served as a shift, and was fastened by a button to each shoulder; the robe, which forms more ample masses, encircles the lower part of the figure. Without recurring to signs or allegories, the sculptor has by action or form rendered apparent the several degrees in which the mind is influenced. In one this is effected by a slight movement of the head; in another by the motion of parts only; in others by the entire action; indeed, whether regarded for their conception, composition, beauty, or expression, there are few works in existence which afford examples of more perfect unity, greater variety, or purer style.

There are passions, and even degrees of passion, which declare themselves in the countenance by contractions so disagreeable, and in the body by action so violent, that they are incompatible with, and destructive of, beauty. The Greeks, perceiving this, invariably took that middle course by which a certain degree of beauty was always preserved; and it is remarkable that there is no instance, in the best times of Art, of any violent passion, such as Anger or Despair, being personified. Desolation, as we see

in the Niobe, was marked by simple affliction, and everything which could debase the beauty of Nature, was avoided.

To avoid any excess of expression which might offend, even the Furies were characterized rather by attributes, and were personified under agreeable forms. Pan also was represented anciently with human feet, and appears in the coins of Arcadia as a beautiful young man. All the statues of that god, as seen with goats' feet, and an expression in the head of that animal's propensities, are believed to be of a later age.

But to return to the school of Praxiteles, in which the stern dignity of Sculpture was displaced by an almost feminine tenderness both in feeling and execution, the rigid character of the earlier schools almost expiring with the younger Myron.

Undoubted examples of the great master of this period may be seen in the Apollo Sauroctonos, or Lizard Killer, and in the statue of "Cupid bending his Bow." There is also a beautiful little specimen in the British Museum, a copy, most probably of the same period, from the celebrated statue which occasioned the pleasant story of Phryne, the Mistress of Praxiteles. The small statues, also in the British Museum, of the Periboëton, are received as the work of Praxiteles; but the Apollo Sauroctonos, in the Villa Albani, the most precious monument in bronze which probably exists, is the most characteristic of his style. The Apollino, in the Tribunal of Florence, is another example of youthful beauty and grace. There is no antique statue that surpasses it in elegance of proportion or harmony of form. We may also class as a work of this period, a bust of Atys in the British Museum.

In the ideal style of that class of art termed androgynous—in its treatment, uniting the forms of the two sexes—this age supplies many examples, in statues of Apollo, Bacchus, Cupid and Adonis.

An ideal standard of female beauty, according to fixed principles, had long preceded the Praxitelian age; but it was a beauty raised above the limits of mortality. In the combination of grace, and all which could add loveliness to form, this age was peculiarly distinguished. The art of the former school had its foundation in religion, and was intended to command respect, rather than to excite pleasure; but not many years after the expulsion of the Persians luxury had attained to an Asiatic pomp, and every refinement was sought after that could please the senses. But we must not confound the state of Athens with the country around it—that city, according to Dicearchus, who wrote about the period of the death of Alexander the Great, being of the meanest character, as regarded the houses of the citizens, whilst unbounded magnificence was found in the country residences of the Athenians. Their minds, in the interval of peace, had received that polish which the cultivation of graces bestows, and the artist found his talent as highly in demand for pleasurable as for sacred purposes. Every motive had, from the earliest times, been given by the Greeks for the cultivation and improvement of beauty: games had been instituted at Elis, and the prizes were consecrated in the Temple of Minerva; and so cautious were they to avoid everything which could distort, or even discompose the features, that Alcibiades refused to play upon the flute, as it had that effect, and was, in this, as in many of his habits, followed by all the youth of Athens.

Among the statues of this period, one of Venus, at Woburn Abbey, and another at Newby Hall, may be classed as examples of the highest beauty. The statue at Woburn is rather below the standard of nature, being not more than four feet ten inches in height. The accessories in the Newby statue, as well as in the Venus de Medicis, leave little doubt that both were executed after the age of Lysippus, or about the dispersion of his immediate school. The Cupids which are attached to the dolphins in the latter, under the form of winged children, are a late personification; Eros, or Love, in earlier periods, being represented as a beautiful youth.

After the subjugation of Greece by Philip of Macedon and his son, the history of the arts, as of the country itself, declines in interest. The jealousies and collisions for power with the princes who followed, and the struggles of the people to recover their independence, terminated that calm which had contributed so much to the promotion both of Sculpture and Painting. The former was, however, partially supported, and works of the time are still found in a pure style; but in Greece generally, adulation to succeeding, but more particularly to successful princes, introduced a new practice, which seems to have hastened the fall of Sculpture. Their money, which, from immemorial times, had been sacred to the gods, and, except a local device, bore their image only, was now impressed with the forms and types of their princes, and, about 280 years B.C., the age of portrait sculpture commenced, and heroic art declined.

But nothing perhaps contributed more to the degradation of Art, than the disuse of the means afforded for the contemplation of beautiful nature in the decline of the public games. The olive crown had ceased to inspire its wonted emulation, in the cultivation of the body for athletic rivalry; and that manly and patriotic feeling which had hitherto distinguished the Greeks generally, but the Athenians more particularly, was debased by the frequent and barbarous exhibitions of hired combatants.

Under the Ptolemies and Seleucidæ, Art occasionally found munificent protection, and, though rapidly approaching its decline, it still was tempered with a portion of that sublimity of which we have several very beautiful examples remaining; but its power had ceased with the causes which produced and sustained it; and with Lysippus the Golden Age of Sculpture expired.

The Professor then proceeded to consider the Roman period. The early history of Rome, he remarked, leaves us in no great surprise that a people who were soldiers from necessity, and dependent at first solely on their personal courage and vigilance for their safety, and who were surrounded by neighbours as rude and unpolished as themselves, should have had neither the inclination, nor, for a long period, the means of cultivating gentle or elegant pursuits. Marcellus, who sacked Syracuse 212 years B. C., introduced among his countrymen some slight taste for the Fine Arts, but more particularly for Grecian elegance, by transporting the statues and pictures of Syracuse to Rome: and Mummius, 147 years B. C., extended their influence by taking to Rome the spoils of Corinth; while Sylla, still later, by the dismemberment of Athens, Delphi, and Elis, filled Rome with the rarest productions of Grecian art. It is from this period, which may be considered that of the total subjugation of Greece to the Roman power, that we may date the decline of Sculpture in that country.

On the full establishment of the Roman dominion, the elevation of Julius Cæsar, and subsequently of Augustus, to the supreme power, was auspicious to the preservation of Sculpture; for it appears that an inclination towards the Arts was superadded to the policy which directed those emperors in the increase of the splendour and magnificence of Rome. Nor was this confined to the capital; the fixed authority of the emperors, and the general security of the country, afforded leisure for the cultivation of elegant pursuits, and a desire of improvement pervaded all ranks, and extended itself throughout every province of that vast empire. Under Tiberius, Caligula, Claudius, and Nero, the character of Art which prevailed at Rome does not, however, appear to have been sufficiently influenced by the authority of the fine examples which they had been at so great pains to collect from every part of Greece. Tiberius corrupted the taste, and Caligula caused many of the ancient statues to be mutilated by removing the original heads, and substituting his own portrait in their place. Sculpture, during the reigns of these emperors, was, unfortunately, fettered by the caprice of its employers, or was too often degraded by being made the vehicle of depraved sentiment,—a personal, rather than a national demand for his talent, directed the practice of the artist to individual personification, and even in this the simplicity of the art was invaded by the gorgeous apparel which the vitiated taste of his employers required in the admixture of the marbles of Egypt and the East, which had now become objects of attraction. The same departure from simplicity pervaded their architecture, every member of their temples or public edifices being encumbered with a profusion of ornament. Notwithstanding the great quantity of sculpture that was produced in the time, the reigns of these princes passed away without having produced a single Roman sculptor of original genius, nor can we refer to any very remarkable work in heroic composition. The fact of there being no native artists may be inferred from the circumstance, that all the names recorded by Pliny, of eminent men of those periods, are Greek. In intaglio and the more delicate productions in metal, Dioscorides, Agathopus, Possidonius of Ephesus, Lædus, Pithias, and Zopyrus, held a high rank. In Sculpture, Craterus and Pythodorus, Polydectes and Hermolaüs, with Aphrodisias of Tralles, are named with honour. The groupe of Hæmon and Antigone has been ascribed to this age, but on doubtful authority.

Under Trajan, Sculpture again acquired some strength. In the preceding reign, indeed, some talent appeared in that which we may presume to consider Roman Art, as is evinced in the relievi in the Arch of Titus; but they do not approach, either in spirit or completion, the productions of even the last ages of Grecian art; they attract by their general combinations, and excite our interest rather from the eventful triumph they were intended to record, than by any great merit they possess as works of art.

This age—namely, of Trajan—may be considered the most characteristic of Roman art, and the sculpture round the column erected in honour of that emperor's victories over the Dacians, affords the best example we have, in connected composition, of their power of invention and execution. It is to be regretted, that there is no work amongst the Greek relievi which can be referred to as a just parallel with this work. The Phigalian frieze, though in the same class of relievo, is opposite in principle and design, being wholly a work of fiction; and the Parathenaic frieze, though nearest in its application as an historical design from its recording an immediate fact, is most distinct in the treatment and quality of its relief.

Hadrian had a peculiar claim to the title of Patron of the Arts. He not only contributed to the restoration of many of the temples in Greece, and to the preservation of whatever was excellent in ancient Art, but he was a munificent encourager of living merit. Many of the productions of his reign were not unworthy the purest times of Attic Art; and are such close imitations of the school of Praxiteles and Lysippus, as not unfrequently to be mistaken for the works of those sculptors or their scholars. Generally speaking, however, they must be considered as mere imitations—the effects of practice, skill, and industry, rather than the result of original genius; their production was evidently an effort, and though Art was encouraged by the patronage and protection of the prince, the works which had been extracted from Ætolia and Epirus had neither inspired the imagination of the Romans, nor kindled a rival spirit in their artists. Even in this age, we find no mention of any distinguished Roman sculptor; those of the time on record, Aristæus, Zeno, and some others, being evidently Greeks.

From the death of Hadrian we may date the decline, and from the Antonines may see in the works that have reached us the rapid decay, of Sculpture.

Marcus Aurelius felt favourably towards the Arts, but the equestrian statue of that emperor is perhaps the only distinguished work of the age. The peculiarities of this and the following reigns are particularly observable in the treatment of the hair and draperies of their works in Sculpture. In the hair, especially, after the masses were laid in, nearly the whole was worked with the drill.

Although the Severi were well disposed to advance the cultivation of the Arts, Sculpture, under Commodus and his successors, fell with surprising rapidity. In the relievi of that period the incidents were accumulated to a degree which left no room for the display of character. Ideal Art had descended from its lofty station, and common reality had usurped its place. But, on the decline,—nay, on the very brink of its extinction,—it is interesting to find, that the features of good Art are still discernible; and occasionally there appeared works, which, for justness of expression, tenderness of feeling, and vigour of execution, would have done honour to the happier periods of ancient genius; but they were few, and in no regular course, and can be considered only as samples or fragments of a mighty fabric fallen to decay.

In one branch of Art, however, they produced works which will bear comparison with the best of any school or period, and the fine bust of Lucius Verus, formerly in the Borghese Collection; the bust of Commodus at Castle Howard, and many others, are remarkable examples of the consummate ability that was displayed in portrait sculpture.

Under Pertinax, S. Severus, the Gordians, and the first two Valerians, down to Diocletian, Sculpture gradually declined. The reign of the last prince was, indeed, memorable for its productions in architecture, as in the baths which he built at Rome and his palace at Spalatro; but that era was marked by innovation and a profusion of ornament, and the growing connexion with the East, affected and injured Sculpture in even a greater degree than the sister art. In the third century this evil increased; during the fourth every branch of Art approached its fall; until, in the fifth century after Christ, we may date the consummation of its ruin.

We owe the revival of the arts wholly to religion; but Christianity, which had made great progress in the third century, notwithstanding its persecution, had scarcely ascended the throne of the Cæsars, when the Christians in their turn became the persecutors. The altars of the Pagans were insulted, their votaries harassed, and the severest penal statutes enacted against the ancient worship; and the cross was now erected in place of those triumphant ensigns under which the world had been conquered.

Sculpture is much indebted to that pious regard which all nations have shown to the dead. And the early Christians exhibited, as others had done, their good feeling in this respect by the records they placed over the remains of their departed brethren. The crypts of the older churches in Italy, and especially that of St Sebastian, at Rome, abound with these memorials, which almost always have upon them some illustration of, or allusion to, a Christian doctrine.

The subjects most usually treated in these early monuments, were Christ as the "Good Shepherd," the "Ascent of Elijah," "Christ giving his commands to the Apostles," and the "Sacrifice of Abraham." Some of these works were by good artists, and were well composed, and executed with much freedom. Many of the subjects are evidently applications of profane compositions to Christian purposes; and it may not be irrelevant to observe, with reference to this fact, that the early Christians, —perhaps to avoid the constant persecutions directed against them,—symbolized many of their religious rites, borrowing for that purpose such of those usages of the Pagan mysteries as they found admissible.

The clergy, from the sixth to the tenth century, were the only persons who possessed any knowledge of letters, and they still maintained an extraordinary influence, not only over the people, but their princes. The struggle of the church for secular power was daily advancing, and to the establishment of the Pope as a temporal prince may chiefly be ascribed the restoration of Art. Alfred and Charlemagne gave a temporary lustre to the eighth century, but both Sculpture and Painting remained in a most neglected state. Towards the eleventh century the clouds began to disperse, and a few who had studied from the Arabs, in Spain, undertook the instruction of youth, and while they inspired them with a taste for polite literature, assisted in producing a more favourable feeling towards Art.

The history of the arts of design at Pisa, from the tenth to the fourteenth century, supplies the best information on the state of Sculpture and Architecture of the whole of Italy. Pisa may be considered the cradle of the restoration. What the exact state of the Arts was in other countries is very difficult to ascertain, but the most immediately beneficial effects on them in England, and, indeed, throughout Europe generally, may be considered to have been produced by that event which had agitated and given an impulse to every northern nation; namely, the Crusades.

The passions of men generally, but more particularly of the nobility, whose only employment was war, had been much excited by the promoters of the rescue of the Holy Sepulchre; they readily enlisted under the banner of the cross in the hope of those spiritual rewards offered them through the Church, and which, doubtless, assisted by their communication with the East, at that period the chief seat of arts and commerce, induced on their return an attention to the improvement of sacred buildings. It is a curious and interesting fact, that we may date from the second to the sixth Crusade, or from 1144 to 1228, the establishment, in this country, of nearly six hundred religious foundations. Their intercourse with the more polished people with whom the Crusaders had mixed, had attracted attention also to the sister Arts, and Painting and Sculpture were called in to assist in the embellishment of these pious edifices.

It may appear extraordinary, notwithstanding the contemporaneous contrast of customs, habits, and manners of different countries, that all, with very slight deviations, adopted the same style of architecture for religious purposes, and which, from the most rude and simple forms of the tenth and eleventh centuries, reached, in the fourteenth, the most surprising grandeur and beauty. But Sculpture, both in England and in France, was still of the most puerile character. Of this we have many examples in this country, in early fonts and tombs; and little im-

provement took place in ecclesiastical sculpture, to which the art appears to have been exclusively applied, for nearly two centuries, as may be judged by the still rude specimens existing in Edward the Confessor's chapel screen at Westminster, executed in the reign of Henry III., or about 1269. These sculptures illustrate some of the legends of that sainted prince. They were most probably by English artists, but we find from many examples which might be quoted—(amongst which is the sculpture of the screen discovered behind the altar of New College, Oxford, which was built by William of Wickham, nearly fifty years later than the above period)—that although the art had not advanced greatly in execution, there is strong evidence that those works were directed by very superior men, as they display not only great knowledge of arrangement, but also exhibit touches of very beautiful feeling.

The Professor said, he considered that the sculptors employed in building the church at Milan contributed greatly to disseminate a taste for the art. After leaving Milan, they distributed themselves about the country, and they not only improved their own style, by studying the works of Arnolfo and Nicola Pisano, but it appears that several Lombards and Germans were employed in assisting Nicola both at Orvietto and Florence. These artists, seeking employment, subsequently spread themselves over the more northern countries, and the Professor thought the result of this communication between the Italian and German sculptors might be traced in England, in four statues (drawings of which he exhibited), which were removed about forty years since from Guildhall, having been originally discovered at Devereux House, the residence of the celebrated Earl of Essex. The union of styles is evident, not only in these works, but in the far greater proportion of the sculpture practised all over the North of Europe, during the thirteenth, fourteenth, and fifteenth centuries. The emigrants from Italy most probably established the style of English sculpture, which lasted in this country down to the time of the Tudors.

Several fine specimens of die-sinking were produced in the age of Elizabeth, but the Fine Arts can scarcely be said to have received royal patronage until the reign of Charles I. Examples of sculpture were few, and those which had any pretensions to excellence were chiefly by foreigners, and, with the exception of the patronage given by the Earls of Pembroke, Arundel, and Burlington, the Arts had little attention bestowed upon them in this country till the reign of George the Third.

ON A THEORETICAL RULE FOR THE COMPRESSION OF WATER.

BY DANIEL MACKAIN, M. INST. C.E.

The extreme elasticity of air, when considered with reference both to the amount of force which we can apply to it, capable of producing important changes in its volume without any great effort, and to the strength of the materials of which the instruments used for ascertaining its compressibility are composed, have enabled philosophers to determine with considerable accuracy the ratio which obtains between the force applied and the resulting condensation of volume.

A considerable time ago it was believed that the compressibility of air was in proportion to the pressure applied; this was subsequently proved nearly 200 years ago, by Boyle, and also by Mariotte about 50 years afterwards; and this law of compression has since been known by the name of the latter. More recently Messrs. Dulong and Arago confirmed the accuracy of the law of Mariotte, by experiments conducted to the range of no less than 27 atmospheres beyond the common atmospheric pressure.

By means of the barometer, the density of air is found to vary according to its mass superincumbent over any given point in the atmosphere, and the numerous experiments made with this instrument have brought to such a degree of accuracy the barometrical measurements of parts of the earth's surface protruding into the air, as to vie with measurements of their heights made by trigonometrical instruments. These degrees of density are measured by a column of mercury, and, consequently, the height of the column indicates the force of compression, and represents the height of the superincumbent mass of air.

The extent of compression which water undergoes, when subjected to force, has engaged the attention of men of science for some time back. In 1762, Mr Canton found that the addition to, or subtraction from water, of a weight equivalent to that of the atmosphere, produced at the temperature of 60° a contraction or expansion of rain water of 46 millionth parts of its bulk, and in sea water of 40 millionth parts; while in mercury it only amounted to 3 millionth parts: showing that the density of the fluid operated on materially affected the results. Thus, in the case of rain water, a force equal to a column of itself $33\frac{1}{3}$ feet in height produced a contraction of 46 millionth parts: of sea water, a column 32 feet in height produced a contraction of 40 millionth parts: and in mercury, a corresponding column of $2\frac{1}{2}$ feet produced 3 millionth parts of compression. Professor Zimmerman of Brunswick, Professor Œrsted of Copenhagen, the late Sir John Leslie of Edinburgh, and Mr Perkins, have made numerous experiments that establish the fact of compression ascertained by Mr Canton, which, at the time his experiments were published, was at variance with the opinions universally entertained on this subject. With the usual haste with which Sir John Leslie speculated on experimental results, he arrived at the conclusion "that the ocean may rest on a subaqueous bed of air," from the apparently greater degree of condensation which force can produce in air, in contrast with that which similar forces were supposed capable of producing on water.

The degree of compression of water, is, however, extremely small; and the force which it is necessary to apply to it, in order to produce any appreciable degree of diminution in volume, is so great in proportion to the limit of rigidity of the materials used in experimental apparatus, that there is much room for doubt, as to whether or not the indications heretofore recorded be not compound measures of the elasticity of water, and of the materials of which the instruments have been formed.

It has occurred to me, that if the results of the experiments were noted, in which great bulks of water were employed, but operated upon by slight forces, that a degree of compression might be ascertained, sufficient to remove much of the doubt that may at present be entertained as to the rigid accuracy of the experiments on which our ideas of the elasticity of water are at present based—further, that, in these experiments, should any analogy be discovered between the ascertained laws which govern the compression of air, and the comparative indications of compression of water, we may take the laws which repeated experiments have proved to govern the compression of air, as analagous rules for the compression of water; and, calculating from them, may compare the theoretical results which the laws would furnish, with similar conditions ascertained by experiment.

Following out this idea, it appears probable that the transmission of water and gas through long ranges of pipes, may, by the comparative forces required to propel given quantities through them, give an approximate rule for estimating their compressibility; for, if water were totally incompressible, there would undoubtedly be some difference between the quantities of air or gas transmitted through a pipe, and that of water by a corresponding force through a similar pipe—the one would accumulate in density according to the force required for its propulsion; while the movement of the other would be like a bar of iron, influenced only by friction.

In the transmission of water through long ranges of pipes, it has been ascertained that the quantity discharged by a pipe of any given internal diameter, is inversely in proportion to the square root of the length—and directly proportional to the square root of the height of the column of water employed to propel it.

The comparatively recent adaptation of carburetted hydrogen gas, for the purpose of lighting towns, has required attention to the laws by which it is conveyed through pipes. Gas is usually forced through pipes by employing a slight column of water, of a height sufficient to propel the required volume with the velocity required. Now, as already mentioned, the laws of compression of gases and air *have been exactly ascertained;* and it is thence evident, that even the slight compressing force usually employed for the transmission of gas, must produce an alteration in its bulk at the place where the motion originates.

The most exact observations made as to the laws by which gas is conveyed through pipes, show that in like manner as water, the quantity which a pipe can discharge is inversely proportional to the square root of the length of the pipe, and directly proportional to the square root of the force employed to propel it. As gas, after having been propelled through a range of pipe, and when escaping from its extremity into the air, will be only of the density due to the pressure of the atmosphere, the proportion of it at the origin of the pipe, or, as is usual in practice, that in the gas-holder, is not only of the density of the atmosphere, but is also of that further degree of compression due to the force applied for its propulsion through the pipes. In all experiments made with pressure-gages along various lengths of pipes, this extra degree of compression is

found to diminish according to the square root of the length of the pipe, thus showing a gradual relaxation of compression, and a steady progression of current.

The ascertained laws of impulsion and of retardation of gas and water being thus exactly alike, it now only remains to ascertain their measure; and if these be found proportional to their density, there appears reason to believe that water, under proportional forces, is as compressible as air.

I shall endeavour to support these views by the following facts and deductions from them :—

As water is 825 times heavier than air, the velocity communicable to air contained in a pipe by the pressure of one vertical inch of water is equal to that of 825 vertical inches, or 68 feet of air; and if gases be referred to, as their specific gravity is usually compared with that of air as 1, the pressure is that of a column of any gas equal to 68 feet, divided by the specific gravity of that gas; thus, one inch of water is equal to $.\frac{68}{560}=122$ feet of gas, specific gravity ·560.

In the Hydrodynamie of Bossut, he states as the result of experiment, that an aperture of one inch in diameter, under the pressure of a column of water 10 feet in height, discharged 8574 cubic inches, or 4·96 cubic feet of water per minute.

By an experiment made at the Leith Gas Works, a hole, one inch in diameter, under the pressure of one vertical inch of water, discharged 17·7 cubic feet of gas, specific gravity 560, in the same time.

Now, comparing these discharges by the square roots of their respective impelling columns, we have

$$\text{Water,} \qquad \text{Gas,}$$
$$\sqrt{10 \text{ feet}} : 4{\cdot}96 :: \sqrt{122 \text{ feet}} : 17{\cdot}33,$$

instead of, as above, the actual discharge 17·70.

Again, Bossut reports, that a hole 2 inches in diameter, with a pressure of 11 feet 8 inches and 10 lines of water, discharged 13,021 cubic inches of water in 21 seconds, or at the rate of 25·52 cubic feet per minute.

It was also found at Leith, that a hole 2 inches in diameter, with a pressure of one inch of water, discharged 69·5 cubic feet of gas, specific gravity, ·560 per minute.

Reducing the fractions of Bossut's pressure to decimals of a foot, and resolving the pressure into columns of the respective substances, we have the proportionate discharge due to these columns :—

$$\text{Water,} \qquad \text{Gas,}$$
$$\text{as } \sqrt{11.736 \text{ feet}} : 22{\cdot}152 :: \sqrt{122} : 69{\cdot}4$$

cubit feet, which may be reckoned to be identical with the result brought out by experiment.

The Abbé Bossut found, by experiments conducted with great care, that a pipe, 2 inches in diameter, 150 feet long, with the pressure of a column of water 2 feet in height, discharged 5,232 cubic inches, or 3·0278 cubit feet of water per minute.

I have been favoured with the results of two experiments made with pipes of 2 inches in diameter, and 150 feet long. These, with a pressure of one vertical inch of water, discharged 22·66 cubic feet of gas, sp. gr. ·560, and with 2 inches of water 35·16 cubic feet.

In contrasting these experiments, it is to be remarked that the pipes are of the same diameter and of the same length; consequently, the only correction necessary is that due to the variation in the height of their respective impelling columns. Thus, as before, the experiment with one inch of water—

$$\text{Water,} \qquad \text{Gas,}$$
$$\text{as } \sqrt{2 \text{ feet}} : 3{\cdot}0278 : \text{so is } \sqrt{122 \text{ feet}} : 23{\cdot}647,$$

the actual discharge with one inch being 22·66; and that of 2 inches of water—

$$\text{Water,} \qquad \text{Gas,}$$
$$\text{as } \sqrt{2} : 3{\cdot}0278, \text{ so is } \sqrt{244 \text{ feet to }} 33{\cdot}443$$

cubic feet—the actual discharge as above having been 35·16.

In 1819, M. Gerard made various experiments with gas apparatus constructed for lighting the Hospital of St. Louis, at Paris, to ascertain the discharges of gas and air through pipes at the distances of 402½, 1233, and 2043 feet respectively from the gasometer. The discharges of air, with a pressure of 0·858 of an inch of water, were 30·205, 18·150, and 13·237 cubic feet per minute.

Not having any direct experiments with water made under precisely the same conditions, I shall only apply the hydraulic formula of Dubuat, to show the similarity of discharges of that fluid under the same circumstances.

0·858 of an inch of water is equal to 58·334 feet of air: with this head the discharge of water by the same pipe, about the distances above stated, would be 36·206, 21·598, and 14·015 cubic feet.

The close approximation of these results will, I hope, be a sufficient warrant to me for having brought forward the subject with a view to provoke further inquiry; whether the calculations I have entered on, or the deductions drawn from them, be correct or not.

I shall now proceed to compare the rates of compression, under this theory, with those indicated by experiment.

Air is found to be compressed into one half its bulk by the addition of a weight equal to that of the atmosphere, or the addition of a force equal to 28330 feet of air. In the same proportions between gas and water, indicated by the impelling and retarding forces in a long train of pipes, water should also be compressed into one-half its bulk, by the addition of a force equivalent to a column of itself, 28330 feet or 5·36 miles.

Professor Leslie estimates that it will be only compressed to this degree at the depth of 93 miles.

It has already been mentioned that Mr Canton had indications which represented the contraction of pure water at 46 millionth parts, and sea water as 40 millionth parts, by the addition of a force equal to the weight of the atmosphere. By the rule of compression followed in this paper, pure water would compress 11·65 parts, and sea water 11·55 parts in a million, with the pressure due to an atmosphere of air.

Zimmerman arrived at the conclusion that sea water compresses $\frac{1}{340}$ part, when under the pressure of 1000 feet of its own body. The present theory indicates that it would contract very nearly $\frac{12}{340}$ parts under the same pressure.

Professor Oersted's apparatus, judging from the engraving in the Transactions of the British Association, seems to have been incapable of measuring with accuracy the forces stated to have been used.

In 1826, Mr Perkins laid before the Royal Society a table of compression of water, derived from experiment, in which he states that of a column of 190 inches of water to have been for

			Parts.
10	atmospheres	...	0·176
100	do.	...	1·385
200	do.	...	2·395
500	do.	...	5·010
700	do.	...	6·961
1000	do.	...	8·855

while by the theory now advanced these compressions would have been

			Parts.
10	atmospheres	...	2·1
100	do.	...	20·0
200	do.	...	36·2
500	do.	...	70·4
700	do.	...	89·1
1000	do.	...	102·7

I cannot avoid alluding to a slight though rude corroboration of the theory now advanced—the belief of seamen in the greater density of water at great depths than is generally admitted. They find a great difficulty in sounding in deep water, except with very heavy leads. From the increased weight of the leads required, and from the diminished effect on the hand when sounding, seamen are almost universally impressed with the idea that the loss of effect is produced by the increased density of the water.

I shall only add, that if water be compressible to the degree I have now advanced, and the substances now stated were incompressible, bricks will float at a depth of 28,330 feet; granite at 56,600 feet, or 10 miles; and cast-iron at 200,000 feet, or 39 miles.

ORDERS OF ARCHITECTURE.

CHAPTER III.

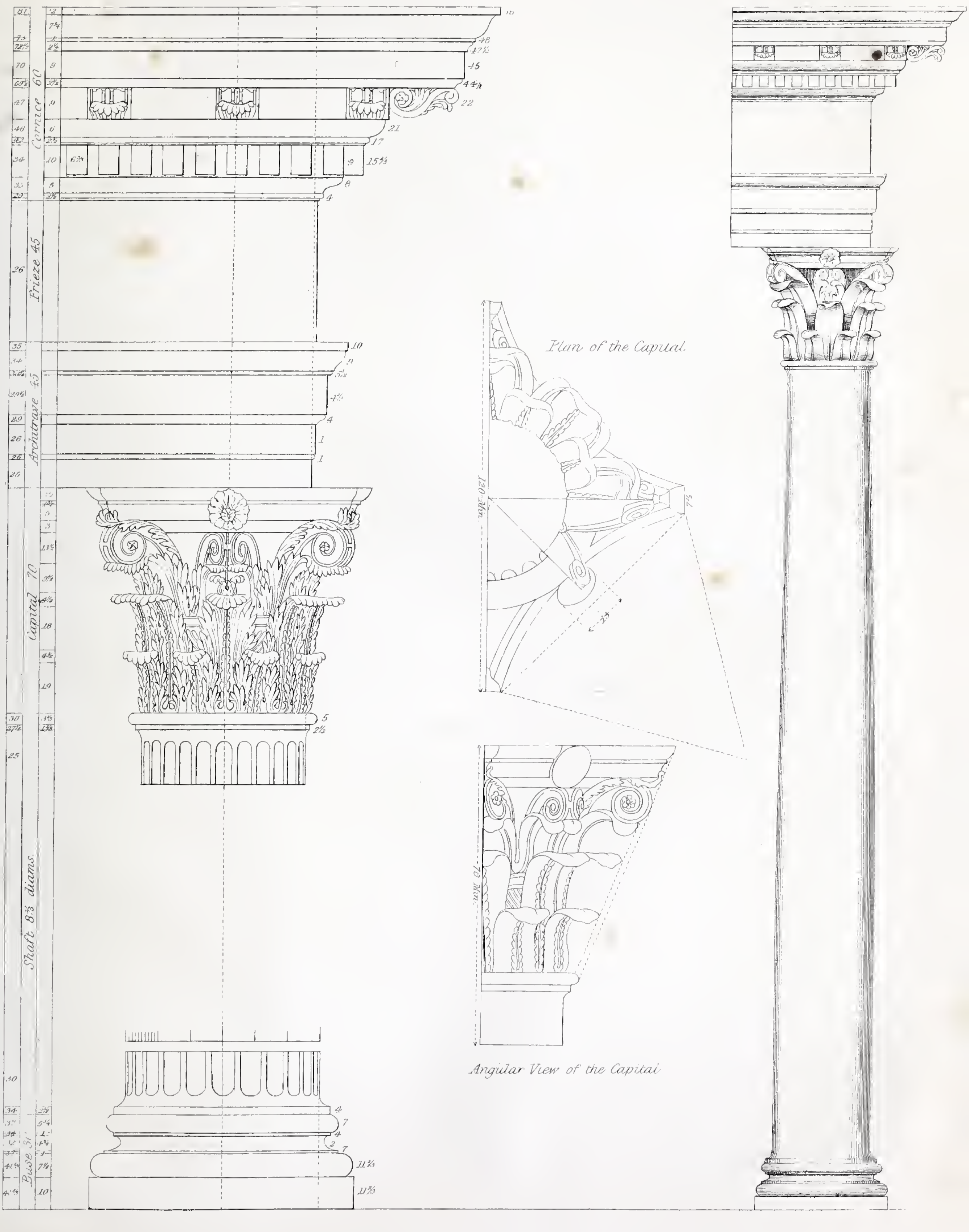
OF THE GRECIAN CORINTHIAN ORDER.

The Corinthian is the third and last of the Grecian Orders. Upon this order the ancients lavished the utmost efforts of their creative genius; it is the most magnificent and elegant of the orders.

The great distinguishing feature of this order is its capital. The

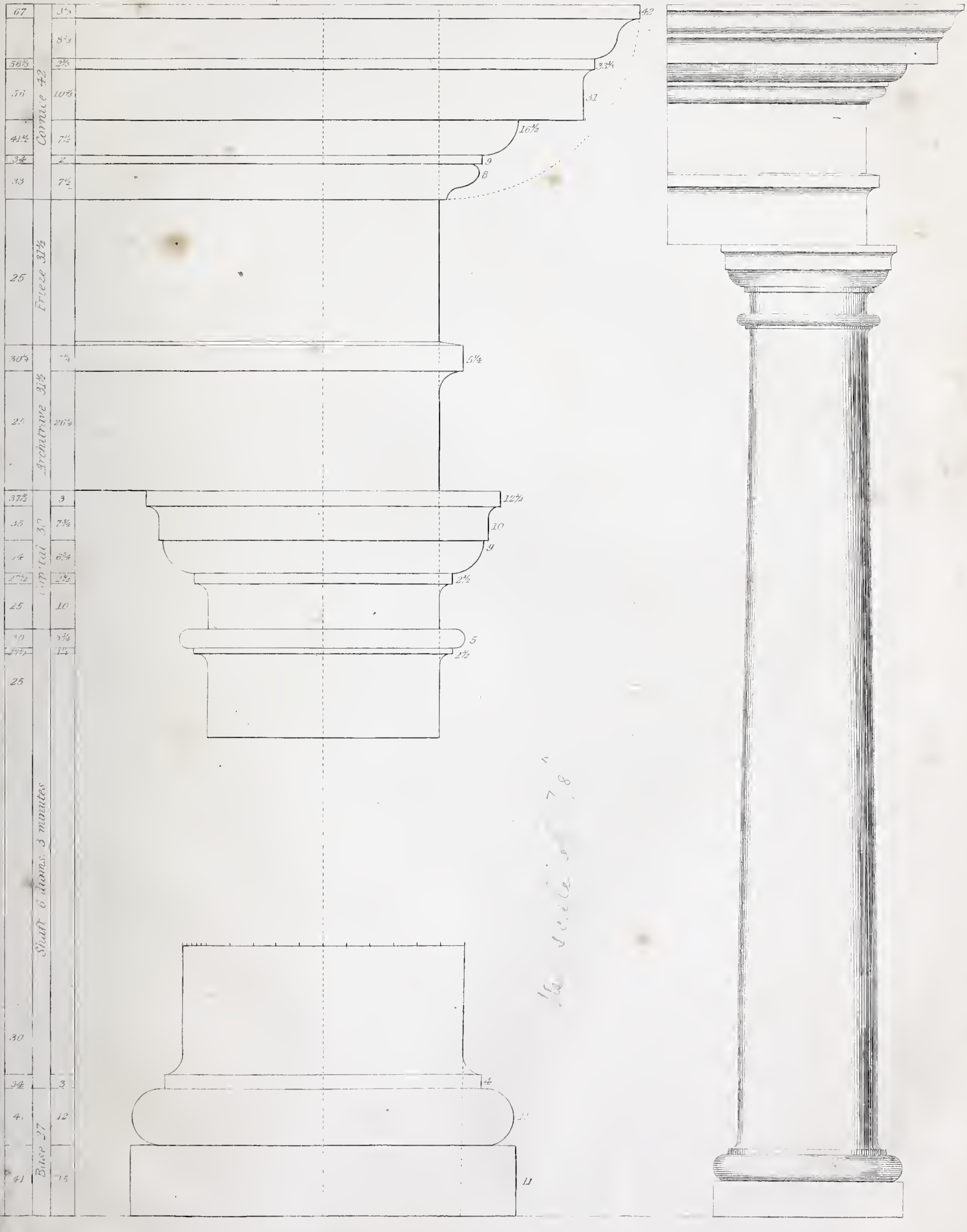
ORDERS OF ARCHITECTURE.

ROMAN CORINTHIAN ORDER.



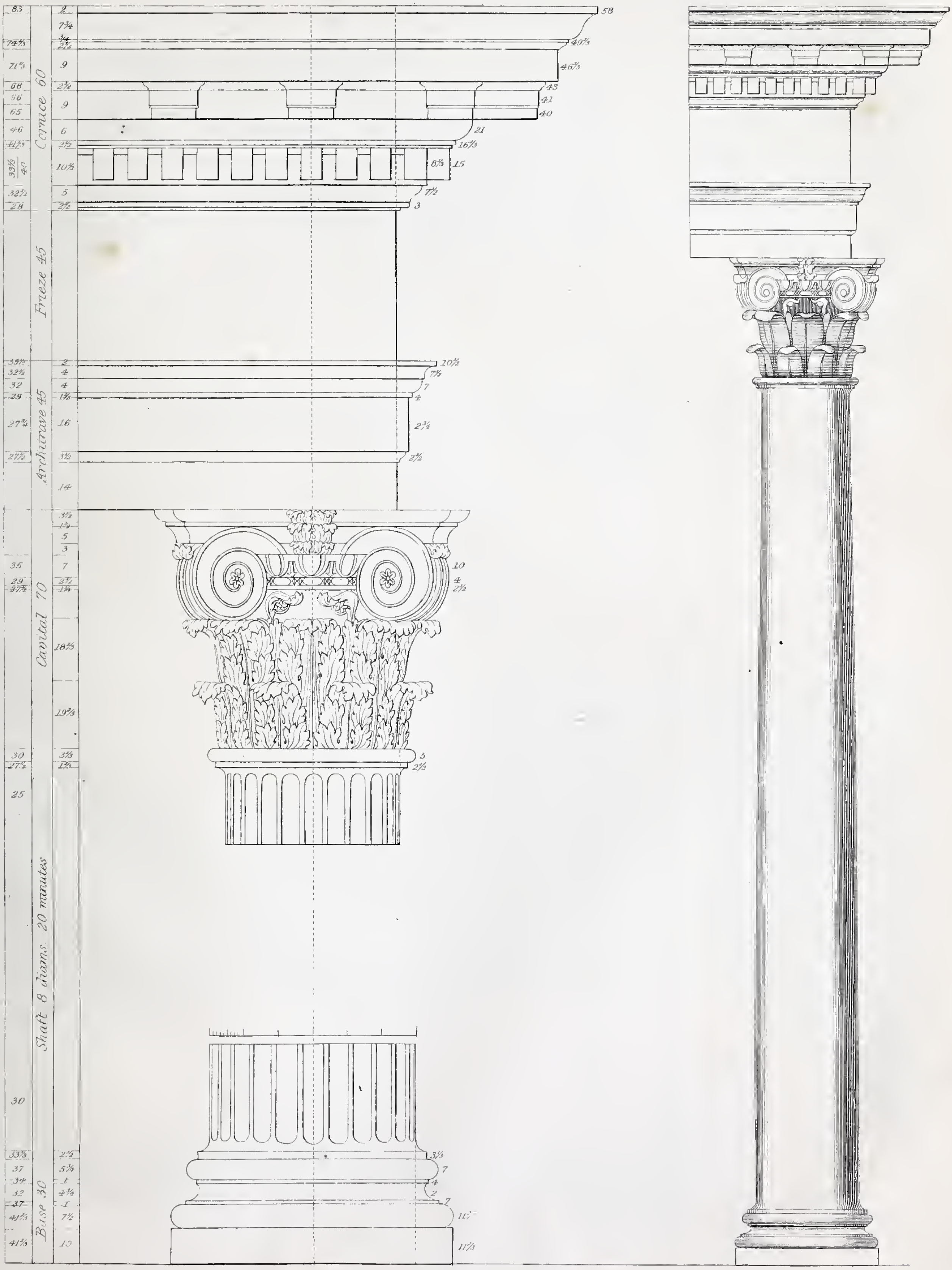
ORDERS OF ARCHITECTURE.

TUSCAN ORDER.

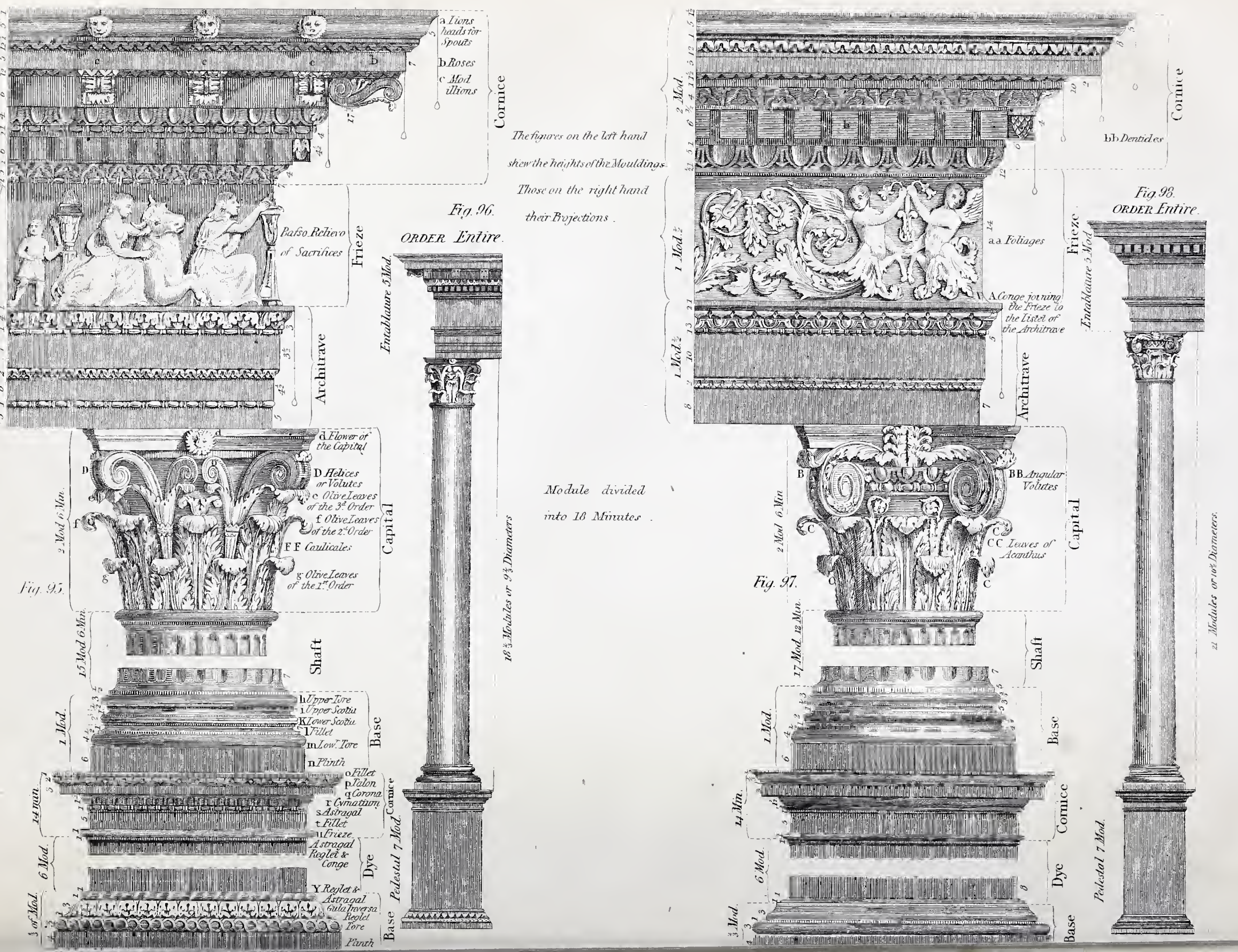


ORDERS OF ARCHITECTURE.

COMPOSITE ORDER.



CORINTHIAN COMPOSITE



capital consists of a solid body or nucleus in the shape of a bell, and hence commonly called the bell of the capital; the bell is surrounded with two tiers of foliage, consisting of acanthus leaves, of which there are 8 in each tier; the upper end of the shaft finishes with an astragal, which appears to bind together the leaves at the roots; surmounting these are 8 caulicoli, or twisted and fluted stalks, springing from between the leaves of the upper tier, and spreading each into two open volutes, which support the abacus; the abacus consists of a square tablet, concave on the four sides or edges, and having the acute angles thus formed, cut away; the edge of the abacus is wrought into an ovolo and a cavetto, separated by a fillet —one of the upper tier of leaves fronts each side of the abacus; the space beneath the abacus unoccupied by the leaves is taken up with slender caulicoli or stalks, which spring from between every two leaves, and proceed to the corners, and to the centres of the sides of the abacus, where they are formed into delicate volutes. The centre of each side of the abacus is adorned with a rosette, or small flower.

The Base of the column, as represented in plate VI, is the same is the Ionic base, consisting of two tori, separated by a scotia, the whole resting on a square plinth. The shaft of the column should be fluted when the entablature is enriched.

In the cornice of the entablature the dentil band is preserved, as in the Ionic order, and is overhung by a fascia, from which enriched modillions project. The entablature bears a close resemblance to that of the Ionic order.

The following are the general proportions of the Corinthian order:—In its general arrangement it is similar to the Ionic; the column is 10 diameters in height; the diameter at the upper end is five-sixths of that at the under end, the taper being therefore one-sixth. The height of the base is half a diameter; the projection of its upper torus is equal to that of the upper fillet of the scotia. The height of the capital is $1\frac{1}{6}$ diameters, of which one diameter is occupied by the leaves and volutes, the remaining sixth being given to the depth of the abacus; the height occupied by the leaves and volutes being divided into three equal parts, the lower part is due to the lower tier of leaves, the second part to the second tier, and the third part to the caulicoli and volutes. The height of the principal volutes is three-fourths of one of these parts. The droop or descent of the tips of the leaves is one-third of the height assigned to them; their form is seen more explicitly in Plate VII, which gives the general form of the foliage before it is cut, in which fig. 1 is the elevation, and fig. 2, the semi-plan of the capital. It will be seen that the circumference of the bell is divided between 8 leaves in each tier. The abacus, which is seen in both these figures, is supposed to be cut from a square plinth shown in dot lines in the plan, the diagonals of which measure two diameters of the column; the curvature of each side is an arc of a circle, of which the centre is formed by constructing an equilateral triangle upon the side of the square, the vertex of the triangle being the centre. Figs. 3 and 4 show the general form and manner of raffling the leaves.

Dividing the whole height of the order into five parts, one of these is due to the entablature, which is therefore one-fourth of the height of the column, or $2\frac{1}{2}$ diameters high. The architrave is three-fourths of a diameter high, the friezo is two-thirds, and the cornice one and a twelfth. Dividing the height of the architrave into 5 parts, one of these is due to the fillet, the quirked cyma-reversa, and the bead—the other four parts are divided equally among the three facia which compose the remainder of the architrave. The frieze is commonly ornamented, though frequently left quite flat and plain. The height of the cornice being divided into three parts, they are disposed among the members in the manner exhibited by Plate VI. The projection of the cornice over the frieze is equal to its height; the projections of the members of which it is composed are given on the plate. The modillions which overhang the dentil band are represented in fig. 5, Plate VII.

Of the Roman Doric Order.

In the progress of their conquests, the Romans extended their dominions over the colonies of Greece, over Greece itself, and over some parts of Asia. It was not till they had acquired the mastery of these, their more polished neighbours, that they possessed any opportunity of becoming acquainted with the architecture of Greece, as well as with its sculptures and paintings. The columnar architecture of the Romans, imitating that of the Grecians, is evidently of the same family, though greatly inferior in simplicity and harmony. The Doric order of the Romans, which we are now to describe, affords an illustration of this remark; it strikingly contrasts with the simple and energetic Doric of the Grecians, and is by no means an improvement on this beautiful order of architecture.

The column of the Roman doric had originally no base, but the addition of a base is certainly an improvement, and renders the parts of the order consistent with one another. The capital has a greater number of members than that of the Grecian, and are of a light and round character, while those of the other are broad and flat. The shaft is more slender than the other, and is very seldom fluted; when it is fluted, the flutes are separated by fillets, as in fig. 6, Plate I, and are 20 in number; the shaft is finished at the upper end with an astragal and a fillet, which support the capital, instead of one or more channels, as in the Grecian. In the capital, three fillets, with a quarter-round and a semi-torus, are intended to represent the ovolo and annulets of the Greek capital; and the height of the abacus, instead of being plain, is divided into a projecting fillet, a cyma, and a fascia.

The Architrave is, like the other, furnished with a band along its upper edge, from which the fillets and guttæ depend. The guttæ also are six in number, but are coniform instead of cylindrical, and project from the surface of the architrave fully more than half their diameter. The face of the architrave is vertical, and stands in a line with the superior diameter of the column, though it is sometimes set a trifle within the point. In the Frieze, the triglyphs project from, instead of being coincident with, the architrave; and those next the angle of the building are, as represented in Plate VIII, placed directly over the centre of the column, instead of being on the angle; the glyphs, of which there are two wholes and two halves, are finished square at the upper edge, and the tops slope downwards towards the back at the same angle with the sides.

In the Cornice, the members are all lighter than those of the Grecian, (there is, in fact, a greater sub-division) with the exception of the Mutules, which are boldly developed, and have no guttæ

Besides the special dimensions which we have given in Plate VIII, we may state the following general proportions of the order: —Dividing the whole height of the order into five equal parts, one of these is given to the entablature, the height of which is therefore one-fourth of that of the column. The column tapers one-sixth throughout the shaft, and is 8 diameters high, of which one diameter is distributed equally between the capital and the base. The plinth in the base is one-third of the height. The height of the capital is nearly equally divided between the abacus with its mouldings, the ovolo with its fillets, and the neck.

The Entablature is two diameters in height, and being divided into 8 equal parts, these are distributed among the cornice, the frieze, and the architrave, in the proportions of 3, 3, and 2. This distribution contrasts strongly with that of the entablature of the Doric. The height of the architrave, which is half a diameter, being divided into three, one of the parts is due to the band, fillet, and guttæ, of which the height of the band is equal to that of the fillet and guttæ together. The frieze is three-fourths of a diameter in height: it is divided horizontally into triglyphs and metopes, of which the former are each half a diameter in breadth, and on the whole depth of the frieze—dividing the breadth of the triglyph into 12 parts, the extreme twelfths are due to the semi-glyphs, and the remaining ten parts are distributed equally between the two whole glyphs and the three vertical plane surfaces or *shanks* which separate them, two parts being given to each member. The plat-band or fascia, which crowns the triglyph, is one-eighteenth of its height. The cornice is three-fourths of a diameter high. The breadth of the dentils is the same as that of the triglyphs, and their projection is equal to their breadth.

DESCRIPTION OF THE ELECTRO-MAGNETIC COIL,

FOR PRODUCING SHOCKS FROM A SINGLE VOLTAIC PAIR.

The effect that a long helix of copper wire has, in increasing the intensity of a single voltaic pair, was first noticed by Dr Faraday, in 1834. His attention was drawn to the subject, by a communication from Mr Jenkin, which is as follows:—" If an ordinary wire of short length be used as the medium of communication between the two plates of an electromotor consisting of a single pair of metals, no management will enable the experimenter to obtain an electric shock from this wire; but if the wire which surrounds an electro-magnet be used, a shock is felt each time the contact with the electromotor is broken, provided one end of the wire be grasped in each hand." It is to Professor Callan, of Maynooth College, that we are indebted for a most extensive series of experiments on the effect of coils of wire surrounding an iron bar, both as to the increased intensity of the shock, brightness of the spark, and magnetic power in-

duced in the bar. The form of apparatus which he generally used was that of a plain bar of round iron, bent into the form of a horse shoe; but the ends of the bent bar being parallel and of equal distance throughout, in place of being curved as the common permanent magnets are. In 1836, Professor Callan had constructed for the royal college of Maynooth, the largest electro-magnet, of which any account has been furnished to the world. It was composed of a round bar of iron 13 feet long and $2\frac{1}{2}$ inches diameter, bent into the form of a horse shoe, the two ends or poles being 7 inches asunder. The first or primary coil was composed of 7 wires of copper, $\frac{1}{8}$th of an inch diameter; each wire being 70 feet long—they were coiled once round the whole bar. To the end of this wire was soldered that of the secondary coil which was composed of about 10,000 feet of wire, $\frac{1}{40}$th of an inch diameter; it was wound round the bar in the same direction as the thick wire. When the opposite ends of the seven thick wires were connected to the opposite poles of a galvanic battery, consisting of 20 pairs of plates, each 2 feet square, the magnetic force induced in the bar was enormous; so much so that no power employed could separate the keeper, even when the magnet was laid horizontally and the keeper applied to it. A weight of 40lbs. was necessary to turn the keeper out of its horizontal position. The keeper weighed 28lbs, and was curved as on the margin; the height of the arch being 7 inches and the weight applied at the extremity.

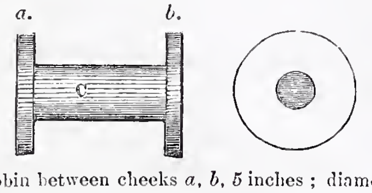
When the large battery of 20 pairs of plates, each 2 feet square, was connected with the thick wire or primary coil, the intensity of the secondary or induced current, in the long thin wires, was so great that on being passed through the body of a large fowl instant death was the result.

Having noticed the form and construction of the electro-magnet for producing shocks, decompositions, &c., we will now describe a few of the various forms of the electro-magnetic coil, or shocking machine. Before doing so it may be remarked that, although Dr Faraday was amongst the first to investigate the effects produced by enclosing a long extended wire or coil in the circuit of a galvanic battery, it is to Mr Sturgeon, the able editor of the *Annals of Electricity*, that we are indebted for an experimental investigation of the form of the coil, as also the size and thickness of wire to be used, and the increase of effect produced by introducing solid or hollow bars of iron into the coil. The great increase of effect, produced by using a bundle of insulated iron wire in place of the solid bar of iron, was first observed by Mr. Bachoffner, who had got one of Mr. Sturgeon's coils.

Description of the coil and apparatus employed for making and breaking the connexion with the battery.

1st. Procure a bobbin of the form and size marked fig 1;

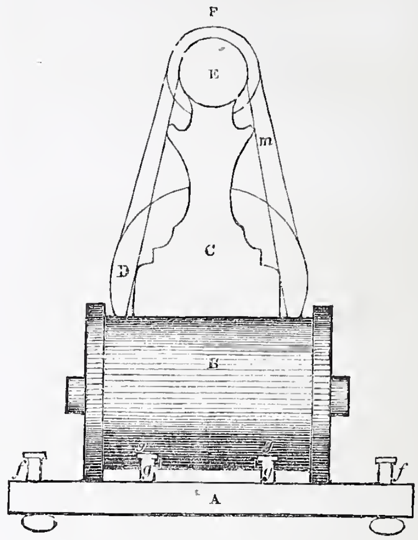
Fig. 1.



length of bobbin between cheeks *a*, *b*, 5 inches; diameter of axle or body, C, 2 inches; ends of bobbin $3\frac{1}{2}$ diameter. Upon the axle of bobbin, coil 300 feet of No. 16 copper wire, well covered with cotton or silk; and for the better insulation of the different layers of wire let a stripe of silk or cotton cloth be put upon each successive layer, until the whole 300 feet of wire is coiled on. For the outer coil procure 1500 feet of covered copper wire, $\frac{1}{40}$th of an inch diameter, which is to be coiled on the top of the thick wire, and in the same direction,—observing the same precaution as to insulation. Let a few inches of the ends of each wire project out from the bobbin, for the purpose of connecting the coil with the battery and apparatus for breaking the circuit. It is to be observed that the two coils are quite separate from each other, the current from the battery passing along the thick wire or primary coil alone;—the shock being produced by the secondary or induced current in the small wire.

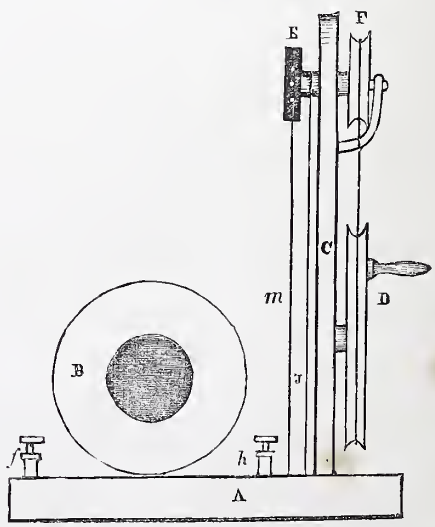
Figs. 2 and 3 represent a front and end view of the machine as it was at first used, with the apparatus for breaking contact; A A the base board of machine, 12 inches square, upon which is fastened the coil B,—the four ends of the coil wire being passed down through the base board for the purpose of battery connexion, and breaking contact; C, pillar of wood for carrying the multiplying wheel D, and the break wheel F; *f f*, binding screws for connecting the battery; *g g*, binding screws for experimenting with the primary coil; *h h*, binding screws for fastening the handles for receiving the shock from the small wire. The break piece E is composed of a round piece of brass, $1\frac{1}{2}$ inch diameter, by half an inch thick, into the circumference of which is bored holes $\frac{1}{4}$th of an inch in diameter, and about $\frac{1}{4}$th of an inch separate. All round, these holes are filled with pieces of ivory or bone, and the surfaces of the brass and ivory are then turned true in a lathe. The break E is in metallic contact with the

Fig. 2.



arbor of the small pulley, F. To one end of the thick wire of the coil is soldered a stout wire, J, which passes up through the base board, and presses upon the arbor of the small pulley, F; the other end of the thick wire is soldered to the binding screw, *f*, of the battery. *m*, a wire pressing upon the break piece E, and

Fig. 3.



passing down through the base board, is connected to the other binding screw *f* of the battery. This completes the arrangement of battery connexion, and of breaking contact. The binding screws, *g g*, are for connecting any piece of apparatus for producing decomposition, &c. *h h*, as already stated, are screws in connec-

tion with the long thin wire, to which are attached the handles for receiving a shock; or if used for medical purposes, a pair of sponge directors are substituted in place of the brass handles. With a Daniell's battery of a pint capacity, the shocks produced by this machine are quite intolerable, and the decomposition of water is easily accomplished.

Figs. 4 and 5 represent another form of the machine,—the

Fig. 4.

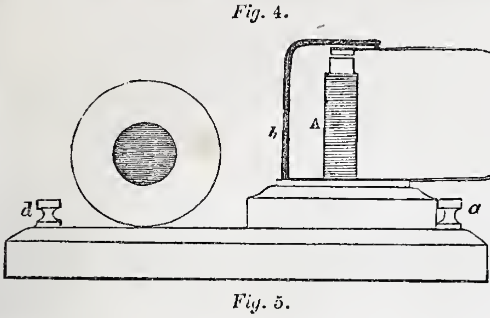
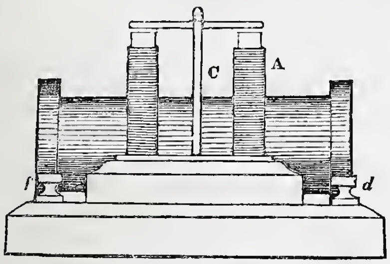
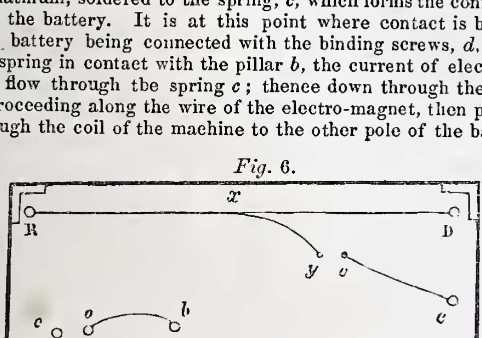


Fig. 5.



only difference being in its having a self-acting contact breaker, in place of the multiplying wheel and disc. The coil is constructed in every way similar to fig. 2. The mode of breaking contact is as follows:—A is a small electro-magnet made of soft iron, round the poles of which are coiled about 4 feet of covered wire, of the same size as that of the primary coil; one end of which is soldered to the binding screw, *a*, to which is also attached one of the ends of the primary coil,—the other end of the wire, which is coiled upon the magnet, is soldered to the brass pillar, *b*, which rises up through the base of the machine. The keeper of the magnet is attached to the brass or copper spring, *c*,—the strength of which is just sufficient to carry the keeper up, off the poles of the magnet. To the end of the spring, *c*, is soldered a wire proceeding from the binding screw *d*. Upon the end of the arm of the pillar, *b*, is fastened a small piece of stout platinum wire, which presses upon another piece of platinum, soldered to the spring, *c*, which forms the connexion with the battery. It is at this point where contact is broken. The battery being connected with the binding screws, *d, f*, and the spring in contact with the pillar *b*, the current of electricity will flow through the spring *c*; thence down through the pillar *b*, proceeding along the wire of the electro-magnet, then passing through the coil of the machine to the other pole of the battery.

Fig. 6.



The circuit being now complete, the magnetism induced in the soft iron attracts the keeper downward and breaks the circuit at the point where the pillar and spring are in contact. The rapidity with which the keeper is attracted and lifted, produces a loud humming noise, and a bright spark is seen at the surface of the platinum.

Fig. 6 represents the under side of the sole of the machine, showing the way in which the different wires are connected; R S, the two binding screws for connecting the battery. To S is soldered a stout wire leading to the spring, *c*; the current proceeding along the spring, *c*, thence down the pillar, *b*, it arrives at *o*. At this point is connected one end of the wire that is coiled on the magnet; the other end of it comes out at *m*, and is connected with the binding screw, A, and the end of the primary coil, *y*. From the binding screw, R, a wire is carried to the binding screw, D; the other end of the primary coil were, *y*, is soldered to this wire at the point, *x*; *v v* are the two ends of the small wire, and are soldered to the binding screws, *e e*, to which are attached the handles for giving shocks.

HOW TO MAKE A CHEAP VIOLIN.

In No. CCCC. of the *Penny Magazine*, there is a paper entitled "How to make a cheap Violin," in which the construction of the violin is taken up in a scientific point of view by M. Savart, a distinguished natural philosopher of France. He investigated the sources of sound as connected with the violin, in order to determine what were and what were not essential parts of the instrument. After which he made one as follows:—1st. Instead of having the face and back of the body curved, he formed them of two pieces similar in size and direction of grain, $\frac{1}{6}$ of an inch thick at one edge, and $\frac{1}{12}$ of an inch at the other, united by their thick edges. 2d. The sides were made perfectly straight, instead of being hollowed out. 3d. The bridge was made a little higher than usual, to suit the altered shape of the body. 4th. The strengthening bar, or bar of harmony, was placed under the middle of the instrument, instead of at one side of the middle. 5th. The holes in the upper surface were straight, instead of being curved like an *f*. 6th. The sounding part was placed very near one of these holes. 7th. The sides of the instrument were deeper than in ordinary violins, so that its internal capacity was greater.

Mr. Peld, of Coalcleugh, made one according to the above directions, of American fir wood, which he found quite superior to the ordinary run of violins, if not equal to the very best. The dimensions are as follow:—Length, 14 inches; width at the bottom end, $8\frac{1}{2}$ inches; width at the top end, 6 inches; depth, $2\frac{1}{2}$ inches; the neck and pegs are the same as in other violins.

For further information on the subject, see No. CCCC. of the *Penny Magazine*.

ELLIPTICAL WHEEL SCREW-CUTTING MACHINE.

This machine, which is of Manchester construction, and which figured at the Great Exhibition, performs, by a very ingenious mechanism, the cutting of the threads of screws in the same manner as by hand.

It is well known that in this operation, if the workman do not take proper precautions, it frequently happens that the thread of the screw is worn away in the very process of being formed. To avoid this, the workman is obliged, instead of turning his tool continuously in one direction, to turn it back when he makes a certain progress—then to advance a little farther—to withdraw it again, and so on.

This alternating movement has both the effect of disengaging the small particles of iron detached by the edges of the screw-cutter, and likewise of allowing the oil to be conveyed by the cutting tool to the parts that have been newly formed. The workman is obliged to take this precaution, not only in forming internal screws, but likewise in cutting screw-threads on metal rods.

The machine which we are about to describe executes this combined movement in the same manner as the workman, and with the greatest regularity. Its construction will be readily understood from the vertical section exhibited in fig. 1, and the end view, fig. 2.

The framework consists of three uprights of cast-iron, joined

by cross bars. Two pulleys, A A′, one of which is fixed and the other free on its axis, receive their motion from any kind of prime mover. The shaft of these pulleys carries a pinion, B, gearing with a larger wheel, C, the latter being mounted on a shaft, K, which extends along the whole machine, and passes beyond the framework on each side.

The wheel, C, transmits its motion to the shaft, K, only by means of the gearing, L, which may be readily disengaged by turning the forked lever, M. To the right extremity of the shaft, K, is riveted a wheel, J, commanding another wheel, I, fixed at the end of a short tubular shaft, which carries the screw-plate, H. To the other end of the shaft, K, is fixed an elliptical cam, D (fig. 2), the axis passing through one of the foci of the ellipse. This wheel gears with another of the same form and size, E, riveted on a hollow shaft, F, of rather large diameter, and arranged in a line with the axis of the screw-plate, H, and with the shaft on which the latter is mounted. It is easy to see that, notwithstanding the eccentricity of the wheels, and even in consequence of that eccentricity, their teeth will continually work into each other. This property follows from the very definition of the ellipse, which, as our readers are aware, is a close or continuous curve—such that the sum of the distances of any point in its periphery to two fixed points within it, termed the foci, is always equal to the major axis or largest diameter of the ellipse.

If, on one of two equal ellipses, any point be taken at a given distance from one of the foci, it is evident that a corresponding point exists on the other ellipse, the distance of which from one of the foci, is equal to the difference between the major axis of the ellipses and the given distance assumed.

It is the same with every point of the two ellipses. If, therefore, the distance of the axis of the two wheels is exactly equal to the major axis above mentioned, and the teeth of one of the wheels be made to gear with those of the other at the proper point, the primary elliptical curves of the wheels will be continually tangents to one another, the sum of the distances of their successive points of contact from one of their foci respectively being always equal to the major axis of each of them, that is to say, to the distance of the axis.

But it is evident also, that the speeds of the different poin ts of the ellipse will not be the same, but that they will increase

Fig. 1.

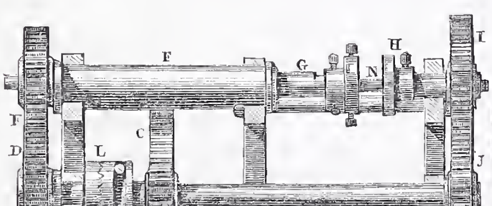
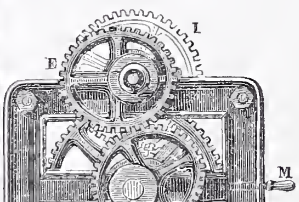


Fig. 2.

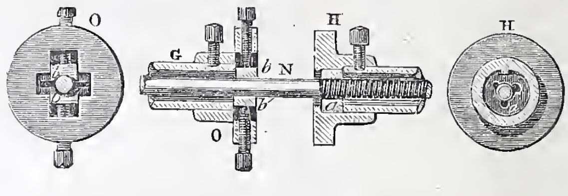


in the direct ratio of the distance of the said points from the centre of rotation. Besides the shaft, K, turning with a uniform speed, and the larger radius of the wheel, D, corresponding to the smaller radius of the wheel, E, it follows that the latter must turn with a very irregular velocity.

Thus, if we suppose that the ratio of the smaller to the greater radius of each of the two wheels is as 1 to 2, when the gearing occurs between the greater radius of the wheel, D, and the smaller radius of the wheel, E, the speeds of the axis, K and F, will be to each other as 1 to 2, or as 2 to 4. If, on the contrary, the gearing occur between the smaller radius of the wheel, D, and the greater radius of the wheel, E, the ratio of the speeds of the same shafts, K and F, will be as 2 to 1. Consequently, for a uniform speed of the shaft, K, the speed of F's rotation will vary from 1 to 4.

To the interior of the tubular shaft, F, is fitted a hollow rod, G, admitting freely of a longitudinal movement, but subjected to the rotatory motion of the external shaft; for this purpose, the rod, G, is ribbed or fluted in its circumference, so as to fit into grooved channels made in the interior of the shaft, F.

Fig. 3.



On the right-hand extremity of the rod, G, is fixed a piece, O, resembling the mandrils of lathes. This piece is open in the middle, and two moveable cushions, *b*, commanded by screws, are adjusted in this opening, as shown in the detail figs. 3.

The rod to be cut, N, is placed in the interior of the tubular shafts, F and G, and is fixed and centered by the screws which press on the cushions, *b*. The screw-plate is formed also of a kind of mandril, in the inside of which is the actual screw-plate, properly so called, *a*, formed of a single piece or of several cushions. This piece is adapted to the extremity of the shaft of the wheel, I, which keeps the cushions in their place, and it is held firm by a fixing screw. The screw-plate is made to *bite* by tapering the extremity of the rod to be operated upon, and the machine is put in motion.

The shaft, F, turning in the same direction as the screw-plate, is made, by the irregularity of its motion, to turn sometimes quicker, sometimes slower than the latter; and consequently the rod to be cut alternately advances and moves back in the screw-plate—this rod, or rather the piece in which it is inserted, being free to slide backward and forward in the direction of its length.

As, notwithstanding the irregularity of its speed, the shaft F makes on the whole the same number of turns as the shaft K, it is evident that, if the same were the case with the shaft which carries the screw-plate, no effect would be produced, inasmuch as the screw would advance and retreat the same length. It is essential that the shaft of the screw-plate should turn more slowly than the shaft, F. For this purpose, the maker has made the wheel, I, rather larger in diameter than the wheel, J.

It is further to be observed, that the ratio of the radius, I, to the radius, J, must at the same time be less than that of the longest to the shortest radius of the elliptical wheels. If this were not the case, the screw would constantly advance in the screw-plate, with unequal speeds indeed, but still without ever moving back.

If the length desired to be given to the screw is greater than the extreme distance between the screw-plate, H, and the mandril, O, it suffices, when these pieces have drawn near each other, to unfix the cushions, *b*, to slide back the hollow shaft, G, to refix the cushions, and set the machine again in motion. The screw, as it is formed, advances through the shaft of the wheel, I.

VENTILATION OF APARTMENTS IN DWELLING-HOUSES.

CHAPTER II.

WINDOW AND VALVE VENTILATORS—DR. REID AND DR. ARNOTT ON VENTILATION—CHIMNEY OPENINGS—AIR SIPHON VENTILATOR.

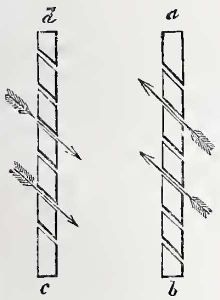
Ventilation, as generally carried out, is divided into three branches:—"Ventilation by Fire-Draught," "Ventilation by Machinery," and "Natural Ventilation." The two former are almost always confined to public buildings; the latter generally to private apartments, although in some cases it is adopted in public buildings, in preference to the two former methods.

It is to the last method that we intend, in the first place, to confine our remarks; looking upon this department as of more general interest than the ventilation of public buildings.

In ventilating the apartments of our dwelling-houses, the first point to be attended to, is the introducing into each a sufficient supply of pure fresh air. The methods of doing this we shall now briefly explain.

The simplest plan yet introduced for admitting fresh air to the interior of our dwelling-houses, is by inserting a plate of perforated zinc, or a perforated pane of glass. In the very miserable dwellings of the London poor, this has been done with marked success. In fixing these perforated plates, they should be placed in the upper row of panes in the window, and at the square farthest from the fireplace. In place of the perforated zinc plates, perforated panes of glass, known as "Lochead's Ventilating Glass," have been largely introduced. The perforations consist of long vertical or horizontal slits; some being somewhat about $2\frac{1}{2}$ inches long by $\frac{1}{8}$ wide, the perforations being about $1\frac{1}{2}$ inch apart. These are not made with their direction at right angles to the face of the pane, but oblique to the face, so as to throw the air upwards or downwards in passing into the room. This is shown in fig. 3, where *a b* represents a pane with the air coming from the outside, and being thrown upwards, while *c d* is placed the reverse way, so as to throw the air downwards.

Fig. 3.

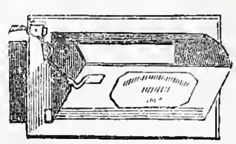


The idea of perforated glass has been carried out by another plan—an approximation to the perforated zinc inasmuch as the perforations are circular, and very close to one another; in place of being at right angles to the plane of the plate, the apertures are oblique. Another method of admitting air, is by means of the glass convex ventilator: this consists of a series of narrow strips of glass arranged horizontally in a frame, and so made that by moving a string the direction of the plates may be changed, and thus the apertures so arranged as to transmit the air upwards or downwards, or be closed altogether. "Moore's Patent Ventilator," shown in fig. 4, is simple and effective; it is so contrived that no action can disarrange or destroy the glass louvres; it does not get easily out of repair, and is opened and closed with facility. The principle of its action is such, that a line being pulled and maintained at any point, opens the louvres, driving the air upwards; on the line being set free, the louvres close of themselves air-tight. All these ventilators may be classed under one head, as "window ventilators," and all are liable to the serious objection, that at night, when the blinds are drawn or the shutters closed, their action is impeded, if not altogether stopped. As the evening is the time when the inhabitants generally congregate in apartments, a greater rather than a less supply of fresh air is then desirable, and to obviate this disadvantage other methods of admitting air have been introduced. We shall now notice a few of these.

Fig. 4.

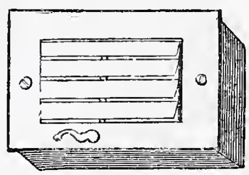
The method generally adopted is to make apertures in the outer wall, admitting the fresh air to spaces behind the skirting board, and making the latter perforated; a supply of air to the room is thus kept up. In this case, the outside apertures should be covered also with perforated zinc, so as to prevent vermin lodging therein. Another method is to admit the fresh air to a space behind the grate, leading it up channels to each side of the fireplace, and ultimately passing it through perforated gratings within the wall, or through perforations in the skirting board on each side of the fireplace. There is yet another plan to be noticed: the lobbies, and passages leading to the rooms, may be well supplied with fresh air directly from the external atmosphere; and this air may be warmed in winter by placing a stove in the hall, or elsewhere. In this case, the lower panels of the doors to each apartment may either be of perforated zinc, or ornamental brass grating, or simple perforations may be made through the wood. In the interior or exterior, as taste or fancy may dictate, small silk curtains may be hung before the perforations; these may be capable of removal, or of being wound up on a small roller; or the window blinds used in railway carriages, and which are easily wound up by means of a small spring, may be used. A large supply of fresh air may thus be given to each apartment. This plan is highly recommended, and wherever it has been adopted it has given great satisfaction. If objected to as an unseemly addition to the doors of the "entertaining rooms," there can be no such objection to its use in the bedrooms.

Fig. 5.



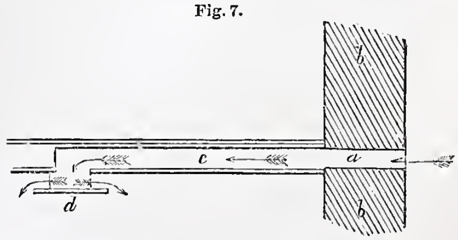
A variety of valve ventilators have been introduced for fixing in the external walls of apartments, and thus supplying them with fresh air. The best known of these is the Sheringham method of ventilation, for the admission of pure air through an external wall. This is shown in fig. 5, and consists of a lid or valve, one side of which is attached to the frame fixed in the opening in the wall near the cornice: this lid is kept open by a spring, and may be closed to any required degree by pulling a cord. As will be seen by the diagram, the fresh air on entering is thrown upwards, and, mixing with the hot air near the ceiling, acquires a considerable amount of warmth before descending to be breathed by the occupants of the apartment. This advantage—as it is termed—is we think exceedingly problematical: the warmth is undoubtedly gained at the expense of purity; the fresh air must be deteriorated by mixing with foul air. The Venetian Ventilator is another contrivance for admitting fresh air through an opening in the external wall. As shown in fig. 6, it consists of a series of louvre plates, moveable in a frame which is fixed in the wall opening near the cornice; by operating on the handle, the quantity of air admitted may be nicely regulated.

Fig. 6.



A method of admitting fresh air to bedrooms has been broached to the Health of Towns Commissioners, and is we think likely to be efficient. An aperture is made in the external wall, *b b*, fig. 7, at *a*, leading

Fig. 7.



fresh air through the channel, *c*, made between the ceiling of one apartment and the floor of another, to an opening, say in the centre of the ceiling of the apartment to which the fresh

air is to be supplied. The aperture in the ceiling has a flat board or disc, *d*, suspended a few inches—four or six—beneath the plane of the opening; this disc will cause the air to be diffused or scattered in its passage into the room.

It is very obvious that the means for admitting air to the interior of apartments, must vary with the local circumstances in each case; these, in fact, naturally regulate or determine the kind of contrivance to be adopted. Provided the supply is ample, and not likely to create disagreeable and very obvious draughts or currents, the method of procuring it may be left very much to be decided by circumstances.

We now come to the consideration of the next important point in ventilation, the withdrawal of the foul air; and here may be given Dr. Reid's remarks on natural ventilation, as an admirable introduction to this department.

"For all ordinary purposes, the natural method of ventilation will be found most eligible—that is, a process by which movements are induced or sustained in the air in the same manner as wind is produced in the external atmosphere, these movements being increased, when necessary, by the action of heat, and by the erection of a shaft or chimney, that the heat may acquire additional force.

"It is much questioned by various individuals, whether a fanner, or some other mechanical power, is not more efficient and economical; but this question is a little more complicated than is generally represented, and the following observations are given with the view of illustrating the more prominent circumstances that bear upon it.

"As air constitutes, in one respect, a balance infinitely more delicate than any that man can make, and as the most trifling increase or diminution in the density of any portion of air leads it to press more or less heavily than before on that which is immediately in contact with it, circumstances, almost too inappreciable at first to be considered worthy of notice, can nevertheless so alter its specific gravity, that it immediately begins to press more heavily than before on that which surrounds it, or to give way before the pressure to which it may still be subjected, if its density be diminished. But though many popular misapprehensions are still entertained on this subject, it is universally acknowledged by all who have experimentally examined it, that the specific gravity of air vitiated by respiration or combustion—the two great processes that deteriorate air in ordinary buildings—is, under ordinary circumstances, less than that of common air; it gives way accordingly, and is pressed upwards by the denser and purer air. Let us imagine, then, an apartment occupied (not inconveniently crowded) by a number of persons standing on a porous floor, and the roof taken off; at ordinary temperatures, the air vitiated there by the human frame requires no mechanical power to remove it. The superincumbent pressure is diminished by the expansion induced in the air as it is heated; but the external atmosphere is permitted to have free access, below as well as above, to the porous floor. Its power, therefore, preponderates, and an upward movement is the necessary consequence, which is accompanied by the introduction of fresh air, and the removal of that air which is vitiated. Here, then, is a species of natural ventilation. All that is essential is merely this, that the natural movements induced by the heat of the body shall not be stopped by any barrier which may be opposed to them. An open roof and ceiling, however, is, in the greater number of climates, inadmissible. Protection is required from the weather, independent of other arrangements; the opening, accordingly, may be contracted. In proportion to the amount of contraction, the temperature of the air, and the numbers on a given space, it now becomes necessary to increase the velocity of the discharge from the apartment referred to. To effect this, if a shaft or chimney be extended from any opening in or near the ceiling, the column of warm air, which soon fills it, increases its power; and, unless an extreme number of individuals be crowded in the apartment, the shaft is sufficient for all ordinary purposes. It acts at all times when the density of the air within is less than the density of the air without; and when this is not the case, its power can still be developed by kindling a lamp or fire, or merely by increasing the temperature of the apartment for which it is supplied, as any of these causes produces the necessary diminution of density or rarefaction within, on which its force depends.

"If, however, it be proposed to use a mechanical power for the same purpose, machinery in the first place, more or less simple, must be prepared. Power must be applied to the machinery by manual labour, by water, by a steam-engine, by a weight wound up from time to time, or in some other way; and however small the power actually required at any particular moment may be, it is more liable to accident, and more skill is required to maintain it in action. A chimney, therefore, from its extreme simplicity, and from the comparatively trifling attendance which it requires, is always preferable in numerous situations, while it involves no severe and long-continued manual labour, such as is apt to be neglected. Further, when properly finished at the top, the wind acts as a power, and, without any fire, often determines the ascent of air."

Dr. Arnott was the first to draw extended attention to the value of the chimney as a means for withdrawing foul air from the interior of apartments, and he invented a valve, known as "Arnott's Ventilator," which is widely used. In a letter to the *Times*, Dr. Arnott entered very fully into the importance of ventilation as a remedial measure—detailing in language so explicit the method by which he proposed to carry it generally out, that we give it here *in extenso*; and this we do the more readily, inasmuch as we are desirous to make these articles as complete a record as the space at our disposal will allow, of the various practical suggestions and plans which the general attention, given by scientific men to the important subject of ventilation, has elicited during the last few years.

"In regard to the dilution of aerial poison in houses by ventilation, I have to explain, that every chimney in a house is what is called a sucking or drawing air-pump, of a certain force, and can easily be rendered a valuable ventilating pump. A chimney is a pump—first, by reason of the suction, or approach to a vacuum made at the open top of any tube across which the wind blows directly; secondly, because the flue is usually occupied, even when there is no fire, by air somewhat warmer than the external air, and has therefore, even in a calm day, what is called a chimney draught, proportioned to the difference. In England, therefore, of old, when the chimney breast was always made higher than the heads of persons sitting or sleeping in rooms, a room with an open chimney was tolerably well ventilated in the lower part where the inmates breathed. The modern fashion, however, of very low grates and low chimney openings, has changed the case completely, for such openings can draw air only from the bottom of the rooms, where generally the coolest, the last entered, and, therefore, the purest air is formed, while the hotter air of the breath, of lights, of warm food, and often of subterranean drains, &c., rises and stagnates near the ceiling, and gradually corrupts there. Such heated impure air no more tends downwards again to escape or dive within the chimney piece, than oil in an inverted bottle, immersed in water, will dive down through the water to escape by the bottle's mouth; and such a bottle or other vessel containing oil, and so placed in water, with its open mouth downwards, even if left in a running stream, would retain the oil for any length of time. If, however, an opening be made into a chimney flue through the wall near the ceiling of the room, then will all the hot impure air of the room as certainly pass away by that opening, as oil from the inverted bottle would instantly all escape upwards through a small opening made near the elevated bottom of the bottle. A top window-sash lowered a little, instead of serving, as many people believe it does, like such an opening into the chimney flue, becomes generally, in obedience to the chimney draught, merely an inlet of cold air, which first falls as a cascade to the floor, and then glides towards the chimney, and gradually passes away by this, leaving the hotter impure air of the room nearly untouched.

"For years past, I have recommended the adoption of such ventilating chimney openings as above described, and devised a balanced metallic valve to prevent, during the use of fires, the escape of smoke into the room. The advantages of these openings and valves were soon so manifest, that the referees appointed under the Building Act, added a clause to their

bill, allowing the introduction of the valves, and directing how they were to be placed, and they are now in very extensive use. A good illustration of the subject was afforded in St. James' parish, where some quarters are densely inhabited by the families of Irish labourers. These localities formerly sent an enormous number of such to the neigbouring dispensary. Mr. Toynbee, the able medical chief of that dispensary, came to consult me respecting the ventilation of such places, and at my recommendation, had openings made into the chimney flues of the rooms, near the ceiling, by removing a single brick, and placing there a piece of wire gauze, with a light curtain flap hanging against the inside, to prevent the issue of smoke in gusty weather. The described effect produced at once in the feelings of the inmates was so remarkable, that there was an extensive demand for the new appliance, and, as a consequence of its adoption, Mr. Toynbee had soon to report, in evidence given before the Health of Towns Commission, and in other published documents, both an extraordinary reduction of the number of sick applying for relief, and of the severity of diseases occurring—wide experience elsewhere has since obtained similar results."

Fig. 8.

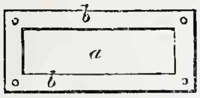
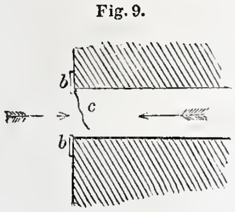
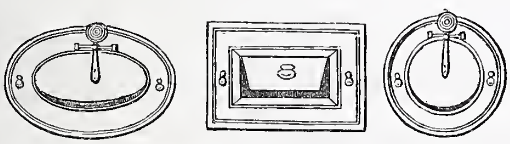


Fig. 9.



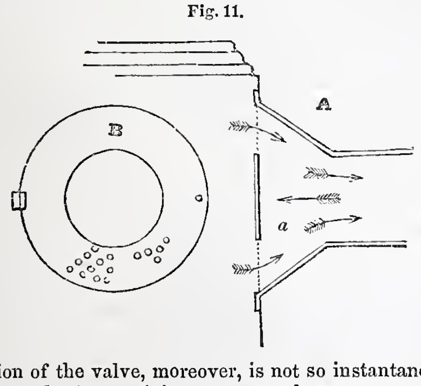
In figs. 8 and 9 we give diagrams, explaining the construction of the simple method of making the ventilator already alluded to. *a b b*, the perforated zinc frame or plate, fastened against the wall, opposite the hole made in it, as *b b*, fig. 9; a piece of silk, *c*, or light stiffish flap, is suspended at its upper edge to the inside of the plate. In the valves manufactured for superior apartments, the flaps are made of brass (as well as the frame exposed to the room), and nicely balanced, so as to close with the slightest current proceeding along the opening towards the room; thus the smoke, if blown down the chimney, closes the valve, and the

Fig. 10.



egress to the apartment is prevented. Various forms of this valve are shown in fig. 10. But however efficient as compared with the merely open fireplace, there are serious objections to it; the working parts are liable to derangement, and a disagreeable noise results from the moving to and fro of the valve;

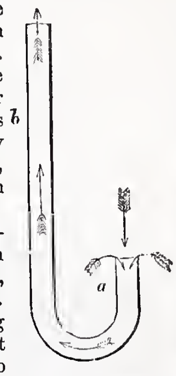
Fig. 11.



the action of the valve, moreover, is not so instantaneous as to prevent smoke from gaining access to the apartment.

To get rid of these objections, Mr. Bryden, of Edinburgh, has introduced a simple chimney ventilator, which, in every case where tried, has been found efficient. For an illustration of this, we are indebted to Mr. Burn's work on "Practical Ventilation." In fig. 11, A is the section, and B the front elevation. An aperture is cut in the chimney breast, near the ceiling, with a conical or trumpet mouth, and the funnel-shaped tube is placed in this. The front of this towards the room is covered with a lid, hinged at one side, so as to open and shut when required; the centre of this lid is left solid, equal in diameter to the diameter of part of the tube. The space surrounding this solid part is punched full of apertures about one-eighth of an inch diameter, or this part is made of perforated zinc. Through these apertures the air from the apartment is withdrawn, and passed to the interior of the chimney. If a down draught takes place, and the smoke of the chimney is forced along the tube, *a*, it strikes against the solid part, and before the smoke finds time to issue out through the apertures, the upward current in the chimney is resumed, and the smoke which has filled the tube is drawn up the chimney.

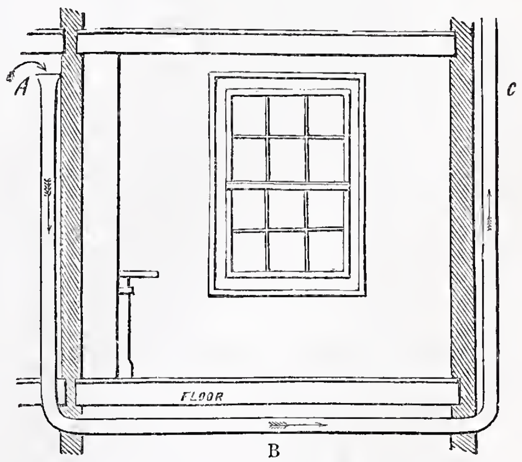
Fig. 12.



In connection with the chimney of the ordinary fireplace, the plan of the Air Siphon Ventilator may be adopted. This method of ventilation, in whatever way applied, is remarkable from its simplicity, its certainty of action, and the ease with which it can be carried out.

The annexed diagram explains the principle of the system. Let a common siphon tube be inverted, as in fig. 12, the leg, *b*, being much longer than the short one, *a*. A current is found to be going up the long leg, *b*, and consequently down the short one, *a*. Now if we suppose the end, *a*, to be connected with the interior of an apartment, near the ceiling, and the other, *b*, opening to the external atmosphere, it is easy to see how the air will be withdrawn from the apartment. Fig. 13 is an exemplification of the method of ventilating an apartment by means of the pipe alone. This method was adopted, with striking success, in ventilating a banker's cellar in London, where nearly all other methods had been attempted, but in vain. It is not necessary, however, to make the long leg of the siphon by means of a tube; in all apartments where there is a fireplace, the chimney flue forms the long leg; all that is

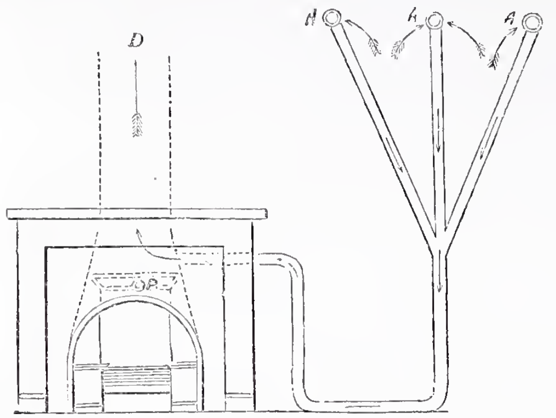
Fig. 13.



necessary is to form the short leg; this opening into the interior of the chimney flue. The first place at which to effect the junction between the chimney flue and the short leg of the siphon is just above the valve of the register grate; if there is no valve, then it should be made at the throat of the chimney, that is, at the point where the "gathering wings" contract to the ordinary size of the flue. If there is not a fire in the grate, the fireplace should be closed by a tight fitting board. In fig. 14 we give the representation of a plan for ventilating

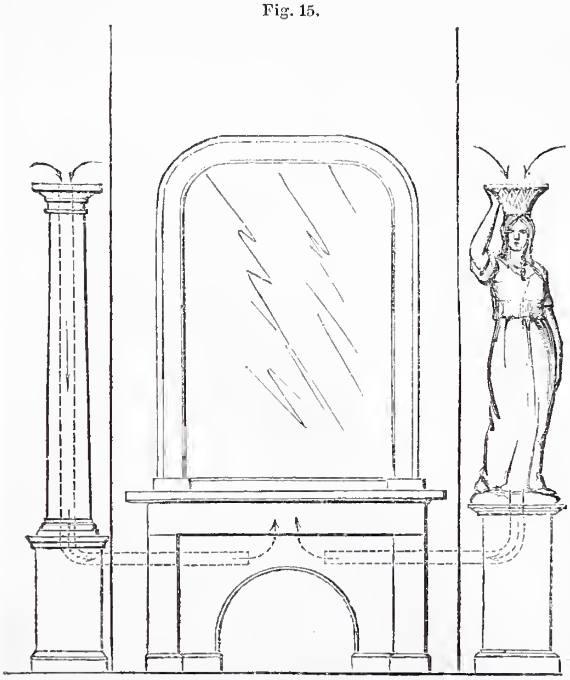
an apartment; the long leg of the siphon branching off into three parts having apertures, A, near the ceiling; they discharge their products to the chimney flue, D. If the fire is not in use, the valve, B, should be closed. In fig. 15 we give another illustration, showing the method of making the short legs of the siphons with ornamental forms. One decided advantage which this system possesses over that where valves,

Fig. 14.



as already described, are fixed in an aperture to the chimney breast, is, the small chance there is that the smoke will be forced down the short and up the long leg of the siphon by any blow-down or gust of wind in the chimney. It will be observed, that before the smoke can be sent into the apartment, as in last figure, it has to pass along the horizontal junction, and then up the whole length of the short leg before it can issue from its mouth. In proportion as the channel of communication between the interior of the chimney and that

Fig. 15.



of the apartment is long, the greater the distance the smoke has to travel; and in all probability before the smoke can find time to reach the apartment, the gust or blow-down in the chimney will have ceased, and the proper ventilating current will be resumed. It is, indeed, just from the circumstance that the distance between the chimney and apartment is so short, where an aperture is made in the chimney breast, that the ventilating valves are faulty; no valve can long be maintained in such efficiency as to prevent altogether the smoke from passing through to the apartment. The chimney, as in the cases we have already indicated, is not taken because the heated current generally ascending it is necessary to create a draught in the siphon, but simply because it offers the facility of a ready-made leg, and thus serves a double purpose. Another advantage, moreover, is, that the ascensional force of the chimney current adds so much to the efficiency of the siphon ventilator.

We shall continue our remarks on this ventilator in next chapter.

GEOGRAPHY.

CHAPTER VII.

SUBDIVISIONS OF EUROPE—COMPREHENDING A BRIEF SKETCH OF ITS DIFFERENT KINGDOMS.

THE BRITISH EMPIRE.—(*Continued.*)

10. DIVISIONS OF ENGLAND.—England is divided into forty COUNTIES or SHIRES, and Wales into twelve, which, with their population, and distinguishing features, are as follow:—

Six Northern Counties.

Name.	Population	Distinguishing Features.
Northumberland....	303,568	Extensive coal fields.
Cumberland..........	195,492	Lakes and picturesque mountain scenery.
Westmoreland......	58,287	Lakes and romantic scenery.
Durham...............	390,997	Extensive collieries.
Yorkshire............	1,797,995	*East*, very fertile; *west*, great woollen manuf.
Lancashire...........	2,031,236	Great cotton manufactories, extensive collieries, and seat of American trade.

Four Counties adjoining Wales.

Name.	Population	Distinguishing Features.
Cheshire..............	455,725	Famous for cheese and large mines of rock salt.
Shropshire............	229,341	Seat of most extensive iron works.
Herefordshire........	115,489	Very fertile and well cultivated; famous for its cider.
Monmouthshire.....	157,418	Abounds in coal and iron.

Ten North-Midland Counties.

Name.	Population.	Distinguishing Features.
Nottinghamshire...	270,427	Inland county; agriculture, hosiery, lace.
Derbyshire...........	296,084	Mountainous; lead mines, mineral waters.
Staffordshire.........	608,716	Noted for its potteries and iron foundries.
Worcestershire......	276,926	A richly cultivated and beautiful county.
Warwickshire.......	475,013	Principal seat of riband manufacture.
Leicestershire.......	230,308	Famed for its breed of sheep.
Rutlandshire.........	22,983	Small, but soil generally rich and fertile.
Northamptonshire..	212,380	Famed for its woodlands and pasturage.
Huntingdonshire...	64,183	Noted for its numerous dairies.
Cambridgeshire.....	185,405	Famed as the seat of a great university.

Ten South-Midland Counties.

Name	Population.	Distinguishing Features.
Gloucestershire......	458,805	Famous for its dairy produce.
Oxfordshire...........	170,439	Fertile; noted for its great university.
Buckinghamshire..	163,723	A fertile agricultural county.
Bedfordshire.........	124,478	Extensive straw-plait and thread-lace manuf.
Hertfordshire........	167,298	Fertile; has a great trade in malt.
Middlesex.............	1,886,576	The metropolitan county of England.
Surrey..................	683,082	A fertile county in the south of England.
Berkshire..............	170,065	A fertile county on the banks of the Thames.
Wiltshire..............	254,221	Inland county south of the Thames.
Somersetshire........	443,916	A fertile county on the Bristol Channel.

Four Eastern Counties.

Name.	Population.	Distinguishing Features.
Lincolnshire	407,222	Noted for its fens and marshes.
Norfolk	442,714	A fertile agricultural county.
Suffolk	337,215	Ditto.
Essex	369,318	Famed for its agriculture and dairies.

Six Southern Counties.

Name.	Population.	Distinguishing Features.
Kent	615,766	Famous for its culture of hops.
Sussex	336,844	Lies on English Channel.
Hampshire	405,370	Agricultural county.
Dorsetshire	184,207	Noted for its freestone quarries.
Devonshire	567,098	Very fertile; mild and salubrious climate.
Cornwall	355,598	Noted for its mines of tin and copper.

The Six Counties of North Wales.

Name.	Population	Distinguishing Features.
Flintshire	68,156	Small county.
Denbighshire	92,583	Ditto.
Cærnarvonshire	87,870	Ditto.
Anglesea	57,327	Island; noted for mines of copper and lead.
Merionethshire	38,843	Mountainous and romantic county.
Montgomeryshire	67,335	Small county.

The Six Counties of South Wales.

Name.	Population.	Distinguishing Features.
Radnorshire	24,716	Mountainous county.
Cardiganshire	70,796	Maritime county
Pembrokeshire	94,140	Ditto.
Caermarthenshire	110,632	A fertile county.
Brecknockshire	61,471	Mountainous county.
Glamorgansbire	231,849	Fertile; vast mines of iron and coal.

11. PRINCIPAL TOWNS:—

Name.	Situation.	Population.	Remarks.
LONDON	On the Thames, in Middlesex and Surrey	2,361,640	The largest and richest city in the world. It is more than 7 miles in length, by 5 in breadth.
Liverpool	Seaport in Lancashire, at mouth of the Mersey	375,955	Next to London in wealth and commerce; is the great emporium of the Irish, American, and West India trade; its wet docks cover upwards of 110 acres.
Manchester	City in Lancashire	316,213	Is the seat of the greatest cotton manufactures in the world.
Birmingham	Town in Warwickshire	232,841	Celebrated for its immense hardware manufacs.; giving work to 70,000 men.
Leeds	In West Riding of Yorkshire	172,270	The greatest seat of woollen manufactures in Britain.
Bristol	In Gloucestershire	137,328	Next to Liverpool as a seaport. Famous for its mineral waters.

The other great *shipping* and *commercial* towns are :—

Name.	Situation.	Population.	Remarks.
Hull	On the Humber, in Yorkshire	84,690	Carries on a good trade.
Newcastle	Northumberland, 10 m. from mouth of Tyne	87,784	Great trade in coals and the manufacture of glass.
Southampton	In Hants	35,305	Chief port for mail steam-packets.
Sunderland	In Durham, on the Wear	67,394	Has an iron bridge 237 feet span.
Stockton	In Durham, on the Tees	9,808	Handsome town with considerable trade
Yarmouth	In Norfolk, at mouth of the Yare	30,879	Has a flourishing trade.
Falmouth	In Cornwall	4,953	Mail packet station; has a noble harbour.
Dover	In Kent	22,244	Nearest port to France; distant 23 miles.

The following are the principal *naval* stations and dockyards :—

Name.	Situation.	Population.	Remarks.
Portsmouth	In Hants	72,096	Chief naval station of Great Britain, its fine harbour could hold the whole British navy.
Plymouth	In Devonshire, at the mouth of the Plym	52,221	Second naval station; has a capacious haven and gigantic breakwater.
Devonport	In Devonshire	50,159	Considered a suburb of Plymouth.
Chatham	In Kent, on the Medway	28,424	A great naval station.
Sheerness	Ditto	8,549	Ditto.
Woolwich	In Kent, on the Thames, 8 miles from London	32,367	Famous for its arsenal, dockyard, and military academy.
Deptford	In Kent, on the Thames	27,896	Has a royal dockyard and fine wet docks.

The other great *manufacturing* towns are :—

Name.	Situation.	Population.	Remarks.
Sheffield	West Riding of Yorkshire	135,310	Noted for its cutlery and plated goods.
Preston	In Lancashire, on the Ribble	69,542	Noted for their large cotton manufactures.
Bolton	In Lancashire	61,171	
Blackburn	Ditto	56,536	
Wakefield	West Riding of Yorkshire	22,057	Noted for their large woollen manufactures.
Huddersfield	Ditto	30,880	
Exeter	In Devonshire, on the Exe	40,688	
Norwich	In Norfolk	68,195	Noted for its fine cathedral, and large silk manufactures.
Coventry	In Warwickshire	36,812	Noted for its manufacture of silk, watches, and ribands.
Macclesfield	In Cheshire	39,048	Great silk manufactures.
Leicester	In Leicestershire	60,584	Great manufactures of hosiery.
Nottingham	In Nottinghamshire	57,407	Great manufactures of hosiery and lace.
Kidderminster	In Worcester, on the Stour	18,462	Noted for its carpet manufacture.
Worcester	In Worcestershiro	27,528	Noted for its porcelain manufacture.
Newcastle-under-Lyne	In Staffordshire	10,569	Extensive manufacture of stoneware.
Gloucester	In Gloucestershire	17,572	Noted for its pin manufacture.

The principal *watering* places of England are:—

Name.	Situation.	Population.	Remarks.
Bath	In Somersetshire	54,240	Noted for its medicinal waters; is the most beautiful city in England.
Cheltenham	In Gloucestershire	35,051	Noted for mineral springs and beautiful scenery.
Leamington	In Warwickshire, on the Leam	15,692	Celebrated for its mineral waters.
Malvern	In Worcestershire	3,911	Great watering place.
Matlock	In Derbyshire, on the Derwent	4,010	Romantic scenery and mineral springs.
Buxton	In Derbyshire	1,235	Noted for its mineral waters.
Harrogate	21 miles west from York	3,678	Ditto.
Tunbridge-wells	In Kent	10,587	Ditto.
Clifton	Near Bristol	17,634	Noted for its hot springs, salubrious air, and fine scenery.

The places chiefly resorted to for *sea-bathing* are:—

Name.	Situation.	Population.	Remarks.
Brighton	Seaport in Sussex	69,673	Favourite resort of George IV.
Ryde	In Isle of Wight	7,147	Beautifully situated on the coast opposite Portsmouth.
Hastings	In Sussex	17,011	Where the famous battle was fought.
Weymouth	In Dorsetshire	9,458	United to Melcombe Regis by a bridge over the Wey.
Ramsgate	Seaport in Kent	11,838	Noted for excellent artificial harbour.
Margate	Ditto	9,107	Much frequented.
Scarborough	In North Riding of Yorkshire	12,915	Beautifully situated; has a considerable trade.

The remaining chief towns in England are:—

Name.	Situation.	Population.	Remarks.
Canterbury	In Kent, on the Stour	18,398	Noted for its magnificent cathedral, in which Thomas à Becket was murdered before the altar, in 1170.
York	In Yorkshire	40,359	Noted for its magnificent cathedral or minster, which is the most splendid specimen of Gothic architecture in Europe.
Oxford	In Oxfordshire	27,843	The seat of a celebrated university, containing twenty colleges and five halls.
Cambridge	In Cambridgeshire	27,815	Seat of a celebrated university.
Windsor	In Berkshire, on the Thames, 22 m. fr. London	9,596	Noted for its castle, a royal residence of the British sovereigns.

The following are the chief towns in Wales:—

Name.	Situation.	Population.	Remarks.
Wrexham	In Denbighshire	6,714	Noted for its flannels.
Caernarvon	In Caernarvonshire	8,674	Noted for its splendid castle, now in ruins, built by Edward I. In it Edward II., the first Prince of Wales, was born.
Holyhead	In a small island off Anglesea	5,622	Irish packets sail from this town.
Bangor	In Caernarvonshire	6,338	Much resorted to for sea-bathing.
Caermarthen	In Caermarthenshire	10,524	Flourishing seaport.
Pembroke	In Pembrokeshire	10,107	Near it are the remains of a magnificent castle.
Cardigan	In Cardiganshire	3,876	Noted for its lead.
Milford Haven	South of Pembrokeshire	....	Safest and most capacious harbour in Britain.
Swansea	In Glamorganshire	31,461	Great resort for sea-bathing; has an immense trade in copper, iron, and coal.

12. Vegetable Productions.—Few of the cereals, the green crops, and roots, or even the fruits, ornamental trees, and shrubs, are indigenous in England; although by long culture and care they have become naturalized. The Vine seldom brings its fruit to perfection, even in the most southern parts of the island; but the following fruits everywhere arrive at perfect maturity, in suitable soil, and at moderate elevations:—the pear, apple, medlar, cherry, gooseberry, currant, strawberry, raspberry, &c.

Besides a great variety of useful and ornamental vegetable products, the following grain and green crops form the staple produce of the country:—wheat, rye, barley, oats, beans, peas, potatoes, hops, turnips, carrots, beet, hemp, flax, rape, buckwheat, woad, madder, teasel, and the artificial grasses.

Under an elevation of 700 feet, we find most of the useful timber trees and ornamental shrubs, arriving at great perfection; such as the oak, beech, sycamore, poplar, elm, ash, hornbeam, maple, lime, laurel, laburnum, chesnut, yew, larch, and pine.

At an elevation of 900 or 1000 feet, the ash, alder, hawthorn, and pine, continue to thrive; but at a higher elevation, the mountain ash, some of the smaller willows, the cranberry, bilberry, juniper, and heaths are also to be met with.

The counties of England most distinguished for *agriculture* are, Kent, Essex, Suffolk, Norfolk, Hampshire, Berkshire, Bedfordshire, Surrey, Sussex, Hertfordshire, part of Lincolnshire, Durham, and Northumberland. One peculiar feature in the vegetation is the royal forests; the most extensive of which are:—the New Forest covering 67,000 acres; Dean Forest, 23,000; Woolmer Forest, 6000; Whittlebury Forest, 5,400; Windsor Forest, 4,400; Delamere Forest, 3,800; and Whichwood Forest, 3,700.

13. Animals.—At no very distant period in the world's history, England was peopled with elephants, hippopotami, the wild horse and ox, bears, hyenas, wolves, elks, the wild boar, beavers, &c.; but these have now given place in a great measure to animals which can be reared and domesticated with profit.

(1.) *Domesticated Quadrupeds.*—Of the varieties of the *horse*, we have the racer, the Cleveland bay, the Suffolk punch, and the old English black; of the varieties of the *ox*, we have the Hereford, the Gloucester, and the Teeswater; of the varieties of the *sheep*, we have the Leicester and South Down; of the varieties of the *pig*, we have the Berkshire and Rudowick. The *fallowdeer* and *roe*, exist in a protected or half wild state, as well as the *urus* or *wild ox*, still preserved as a curiosity in some of the parks of the nobility.

(2.) *Reptiles.*—The adder, common snake, blind worm,

frog, toad, and lizard, still exist, but, except the first, are all perfectly harmless.

(3.) *Birds.*—Of the indigenous and migratory feathered tribes, there is an immense variety; among which we can only name, as being the most curious and valuable, the bustard, quail, grouse, ptarmigan, partridge, pheasant, and black-cock; the geese and ducks of the marshes; the eagle, the nightingale, and the turtle-dove, which only visit the southern counties in summer.

(4.) *Fishes.*—In some of the rivers, salmon are found, but in no great number, and sturgeon are now and then met with; but almost all the fresh waters abound in eels, dace, trout, bream, perch, pike, and other fishes.

The seas surrounding England are frequented by a few of the porpoise family; the herring and mackerel are almost confined to the east coast; the pilchard to the south coast; cod, haddock, whiting, ling, and hake, are found in various parts; oysters are fattened chiefly on the south and south-east; the scallop, rocket, limpet, periwinkle, cockle, &c., are found on rocky shores, where we also meet the crab and lobster.

14. GEOLOGY OF ENGLAND.—So great is the variety of geological formations in England, that we find traces of every stratum which is held to compose the crust of the earth, from the chalk and the newest tertiary beds in the south-east, to the granitic and other primary formations in the western portion of the kingdom. Between these two extremes, most of the intermediate groups are to be found, ranging in a north-eastern and south-western direction; and the animal and vegetable remains, by which each of these groups is distinguished, are found in great perfection. The principal *mineral* productions of England are, coals, iron, lead, tin, and salt—granite, roofing slate, limestone, some marble, building stones of various kinds—alum, potter's clay, fuller's earth, and siliceous sands—copper, silver, zinc, manganese, antimony, arsenic, and plumbago. The mountains and hills of Cornwall, Devon, Wales, and Cumberland, are the main depositories of these metals. COALS are by far the most important of the mineral treasures of England; the principal coal fields are those of Durham and Northumberland, Lancaster, Stafford, and South Wales; *iron* is obtained for the most part from the shales of the coal measures. It is chiefly to her inexhaustible supply of coals, that Great Britain owes her manufacturing and commercial wealth; they have been of more importance, and have conferred more real benefit on the nation, than all that the gold mines of California and Australia could have accomplished. The annual consumption of coals for export and domestic use is calculated to be upwards of 32 millions of tons! Rock-salt is found only in Cheshire and Worcester; and plumbago almost solely in Borrowdale, Cumberland.

15. INDUSTRIAL RESOURCES.—No other nation can vie with England in point of national industry. Her agriculture in most parts of the country has reached a great degree of perfection, and in every part is daily making rapid advances; about a third of the surface is under average cultivation, one part producing grain and green crops, another yielding excellent pasture for fattening and dairy purposes, while a considerable portion is under nursery, fruit, and kitchen gardens, and pleasure grounds. By the invention of machinery, every kind of manufacture has been increased to an enormous extent, enabling England to supply all parts of the globe with articles of luxury and convenience. The annual value of the various productions and manufactures of England has been estimated as follows:—

Production.	Value.
(1.) *Farm Produce*—	
Grain, green crops, live stock, dairy and other produce,	£140,000,000
(2.) *Soft Fabrics*—	
Cotton, including yarn,	£30,000,000
Woollen manufactures, including yarn,	10,000,000
Silk manufactures,	12,000,000
Linen manufactures,	5,000,000
Paper,	1,500,000
Leather manufactures,	13,000,000
Hats,	2,800,000
(3.) *Mineral Productions*—	
Coals,	£10,000,000
Iron,	8,600,000
Copper,	1,200,000
Lead,	920,000
Salt,	400,000
Tin,	390,000
Manganese,	60,000
Silver, alum, zinc, and other metals,	100,000
(4.) *Hardwares, Chemicals,*	
Clocks and watches,	£17,000,000
Cutlery,	2,500,000
Glass,	2,000,000
China and earthenware,	2,300,000
Soaps, alkalies, dyes, &c.,	3,500,000
Machinery, &c.,	incalculable.
Shipbuilding,	do.
Distilling, baking, brewing,	do.

The above is only an approximation to the truth, it being quite impossible to ascertain with accuracy the annual value of productions so fluctuating and various; but, as mentioned above, the sum total of the national income, from all kinds of industry and property, is said to exceed the enormous sum of five hundred millions of pounds sterling per annum!

Nothing has contributed so much to open up the resources of the nation, and raise it to its present wealth and prosperity, as the excellent means of internal communication to which macadamised roads, canals, and railways, have of late given such facilities. The first successful enterprise on a large scale, which showed the advantages of canal navigation, was the Duke of Bridgewater's Canal, which was executed in 1766. In 1777, a connection between Liverpool and Hull was opened up by the Grand Trunk Canal, which united the Trent and the Mersey, and developed the mineral and manufacturing resources in which that district was so rich. The inland navigation of England was completed by the Grand Junction Canal, constructed at a cost of £2,000,000, and which joined the Thames and the Severn with the Trent and the Mersey.

The first railway of any magnitude was the Liverpool and Manchester, which was opened for traffic in 1830. London and Liverpool were connected in 1838; down to 1840, about 1,100 miles of railway were finished and open, and about £60,000,000 had been expended upon their construction.

The following is a table of railway acts of parliament, and the lengths of line sanctioned in 9 years, from 1841 to 1849 inclusive: this includes also the lines which have been abandoned:—

Year.	Acts.	Length.	Year.	Acts.	Length.
1841	19	14 miles	1847	184	1,663 miles
1842	22	67 "	1848	83	300 "
1843	24	91 "	1849	35	50(?) "
1844	48	797 "			
1845	120	2,883 "		805	10,655 miles
1846	270	4,790 "			

On the 1st January, 1849, the number of miles of railway open for traffic in the United Kingdom was 5,127 miles; there are now about 7000 miles completed at a cost of about £300,000,000. Of this sum about three-fourths has been provided by shareholders, and the rest raised by loans at specified rates of interest for specified periods. The number of passengers conveyed by these railways is upwards of 80,000,000, and the total receipts from traffic of all kinds amount to about £15,000,000 per annum.

16. POLITICAL CONSTITUTION.—The constitution of Great Britain is a mixed or limited monarchy, the legislative power being vested in the Great Council of Parliament, consisting of King or Queen, Lords and Commons. The British monarchy is hereditary, provided the person in succession be a *Protestant*, and be not married to a Roman Catholic.

The earliest mention of the word *parliament* in the statutes is in the preamble to the statute of Westminster, A.D. 1272. Great councils of the states existed in England, both under the Saxon and the Norman kings.

In 1297, the 25th year of Edward I., a statute was made which declared that "no tallage or aid shall be taken or

levied by us, or our heirs, in our realms, without the goodwill and assent of the archbishops, bishops, earls, barons, knights, burgesses, and other freemen of the land." In 1327, in the writs issued by Edward III. to the sheriffs to proclaim himself king, the knights, citizens, and burgesses are comprehended under the term Commons, as distinguished from the "prelates, barons, and other great men." In the reign of Edward III., the claim of the Commons was allowed by the king, to entitle them to put a veto upon all enactments which they disapproved of, affecting those great bodies of the people whom they represented. We thus see that the "glorious constitution," which is the boast of Englishmen all over the world, is not one of the great results of "modern enlightenment," but that it arose in the middle of what many are pleased to call the "dark ages!"

Constituent Parts of Parliament.

House of Lords :—		
(1.) *Lords Spiritual.*		
Archbishops (York and Canterbury),	2	
English Bishops,	24	
Irish Representative Bishops,	4	
	—	30
(2.) *Lords Temporal.*		
Princes of the Royal Blood,	3	
Dukes,	20	
Marquises,	21	
Earls,	115	
Viscounts,	22	
Barons,	199	
Represent. Peers of Scotland,	16	
Do. do. of Ireland,	28	
	—	424
Total,		454

House of Commons :—		
(1.) *England and Wales.*		
Knights of Shires,	159	
Citizens and Burgesses,	341	
	—	500
(2.) *Scotland.*		
Knights of Shires,	30	
Citizens and Burgesses,	23	
	—	53
(3.) *Ireland.*		
Knights of Shires,	64	
Citizens and Burgesses,	41	
	—	105
Total,		658

The members of the House of Commons are elected periodically by those of the community possessing certain pecuniary qualifications. A parliament endures for 7 years, unless when dissolved by the monarch. The sovereign is the head of the state, the fountain of dignity and power, and through his ministers carries on the whole executive administration. All laws are published in the name of the sovereign, but they must have previously received the sanction of parliament.

17. Religious Constitution.—The religion of the ancient Britons was Druidism, which was prevalent over the whole island when it was invaded by the Romans. St. Peter, the apostle, is said to have visited Britain and introduced Christianity. The earliest Christians on record are Claudia, and the wife of Plautius, Pomponia Grecia. In the 2nd century, King Lucius, a zealous Christian, sent certain youths to Rome for instruction, who, on their return, converted many of their countrymen. In the reign of Ethelbert, towards the close of the 6th century, the zealous pope, St. Gregory the Great, despatched St. Augustine with a number of missionaries to convert the Anglo-Saxons, many of whom, with the King of Kent, had already embraced Christianity. The Roman Catholic religion continued to be the religion of the country till 1528, when King Henry VIII., being restrained by the old religion from divorcing his queen and gratifying his passion by marrying Anne Boleyn, burst all religious and moral restraint and authority, denied the pope's supremacy, divorced his queen, married Anne Boleyn, and proclaimed himself Head of the Church in England.

The established religion of England is called Protestant Episcopacy—a compound of Calvinism and Arminianism in doctrine, and Episcopalian in ritual and government; being administered by two archbishops, twenty-six bishops, archdeacons, deacons, deans, rectors, vicars, curates, &c.

The annual revenues of the English sees, as redistributed by a late act of parliament, are as follow :—

Archbishops.	
Canterbury,	£15,000
York,	10,000
Bishops.	
London,	£10,000
Durham,	£8,000
Winchester,	7,000
Ely,	5,500
St. Asaph and Bangor,	5,200
Worcester,	5,000
Bath and Wells,	5,000

The other bishoprics are worth not less than £4,000, nor more than £5,000 per annum; except the Bishop of Sodor and Man, who has only £2,000 a-year. The church revenues, estimated at about £3,500,000, are derived partly from land and partly from tithes. Independent of the dioceses, cathedrals, and collegiate churches, there are 10,540 benefices in England.

The following are the number of the places of worship belonging to the different religious denominations in England, according to the census of 1851, the number of sittings which the various churches contained, and the number of attendants on the Sunday on which the census was taken :—

	Places of worship.	Sittings	Attendants.
Church of England,	14,077	5,317,915	3,773,474
Wesleyan Methodists,	11,007	2,194.298	1,385,382
Independents,	3,244	1,067,760	793,142
Baptists,	2,789	752,343	587,978
Calvinistic Methodists,	937	250,678	180,725
Roman Catholics,	570	186,111	305,393
Society of Friends,	371	91,599	18,172
Presbyterians,	161	86,812	60,131
Unitarians,	229	68,554	37,156
Latter-Day Saints (Mormons),	222	30,783	18,800
Brethren,	132	18,529	10,414
New Church (Swedenborgians),	50	12,107	7,082
Moravians,	32	9,305	7,364
Jews,	53	8,438	4,140
Irvingites,	32	7,437	4,908
Sandemanians,	6	956	587
Lutherans,	6	2,606	1,284
French Protestants,	3	560	291
Greek Church,	3	291	240
Isolated Congregations,	543	105,481	64,369
Totals,	34,467	10,212,563	7,261,032

Of the places of worship, there belonged—

To the Church of England, ... 14,077
To other bodies, ... 20,390

Of the sittings, there belonged—

To the Church of England, ... 5,317,915
To other bodies, ... 4,894,648

Of attendants on day of census, there belonged—

To the Church of England, ... 3,773,474
To other bodies, ... 3,487,558

18. Educational Institutions.—The higher educational institutions of England are on a splendid scale of grandeur and magnificence, at the head of which the ancient universities of Oxford and Cambridge stand in proud pre-eminence; that of Oxford containing 20 colleges and 5 halls. University college, Oxford, is said to have been founded in 872; it was certainly a place of study long before the reign of Edward the Confessor, and the greater number of the colleges were founded before the end of the 14th century. The total number of members upon the books of the different colleges and halls of Oxford, in January 1848, was 6020.

The first establishment of Cambridge is also involved in obscurity, but there are grounds for supposing it to have been a seat of learning in the 7th century. The first charter known to have been granted to the University is 15th Henry III., in 1230. The University of Cambridge is a union of 17 colleges, and has an income of £5500 a-year.

England had no other large educational establishment but the Universities of Oxford and Cambridge, till the foundation of the London University in 1828; it now consists of two colleges, University College and King's College.

The other colleges in England are as follow :—

Name.	Locality.
Durham,	Durham.
Lampeter,	Wales.
St. Cuthbert's (R. Catholic),	Ushaw.
Stonyhurst (R. Catholic),	Lancashire.
Manchester New College,	Manchester.
St. Mary's (R. Catholic),	Oscott, Birmingham.
St. Edmund's (R. Catholic),	Hertfordshire.
Homerton Old College,	Homerton.
Highbury College,	Highbury.
St. Peter and St. Paul (R. Catholic),	near Bath.
Spring Hill,	Birmingham.
Stepney College,	Stepney.
St. Gregory the Great (R. Catholic),	near Bath.
Countess of Huntingdon's,	Cheshunt.
Baptist College,	Bristol.
Airdale College,	near Bradford.
Protestant Dissenters,	Rotherham.
Presbyterian College,	Caermarthen.
Huddersfield,	Huddersfield.

Name.	Locality.
Independent College,	Lancashire.
St. Lawrence (R. Catholic),	near York.
Sandhurst (Military),	Sandhurst.
Wesley College,	near Sheffield.
Queen's College,	Birmingham.
Wesleyan Institution,	Taunton.
Western College,	Plymouth.
Haileybury (E. I. C.),	Haileybury.
Addiscombe (E. I. C.),	Addiscombe.

In addition to the above, there are the classical schools of Eton, Westminster, Harrow, Charterhouse, and Rugby; and the elementary schools of the National, and British and Foreign Societies.

The elementary system of education in England is very defective, and totally unworthy of a rich and prosperous country; indeed, everything elementary is left to private exertion and beneficence; in England the number of children attending school is only 1 in every 12 of the population, while in several of the United States there is 1 in 6; in Prussia, 1 in 6; in Holland, 1 in $6\frac{1}{2}$; in Austria, 1 in 9; in Belgium and France, 1 in 10; in Scotland and the Slave States of North America, 1 in 11; in Ireland, 1 in 12.

This lamentable state of matters, however, is at present under the consideration of government, and it is hoped that a national system of elementary education, based on liberal principles, and worthy of the name of England will soon be in full operation.

HORTICULTURE.

CHAPTER IX.

THE MAKING OF HOTBEDS, AND THE CULTURE OF HOTBED PLANTS.

A hotbed, and a hotbed frame, are indispensable to a garden, as without them we cannot, at least in the northern parts of the island, have cucumbers, nor gourds, &c. They are likewise, in every respect, very easy to manage.

They afford protection from the external temperature and weather, and, also, they have a temperature in themselves higher than that of the air surrounding them. In large gardens, this increased temperature is now very generally obtained by means of hot water, steam, and the like; and where such are to be had, they are doubtless the best; but in a small garden we must be content with the old-fashioned plan of using fermenting litter.

The best place for a hotbed is a situation facing the south, and well sheltered from winds. The frame itself is a rectangular box, five feet long, by three and a half broad, with sliding sashes. These sashes should be fitted with glass, but, if desired, oiled cotton may take the place of it. The back of the frame is double the height of the front, so as to form a slope, which is made to face the south.

The earth is thrown a few inches away from a space about a foot larger, in every direction, than the size of the frame. Into this very well-pressed stable litter, or, if that is not easily to be got, leaves, or any vegetable substance that will decompose, must be put. Fresh layers of the litter, &c., are to be then built upon this foundation, each layer being made moderately compact with the foot, until a height of about four feet has been attained. The northern end must be made about nine inches higher than the one facing the south. The frame must then be placed upon it.

Violent fermentation will then commence in the heap, and when this has abated, the surface of the litter is covered with three or four inches of mould, and a temperature of about 58°, at night, should be aimed at. When it has sunk to this, seeds may be sown in it. But after it has acquired the proper temperature, the hotbed, inasmuch as the fermentation diminishes, tends to lose it. To prevent this, linings, as they are called, are employed; *i. e.*, fresh stable litter is heaped around the sides.

THE CUCUMBER.

The first sowing of cucumbers may be made in January, another in March, and a third in June. As is natural to suppose, the first of these is by far the most difficult to manage. A small pot is filled with good earth, and sunk in the earth of the hotbed. In this the cucumber seeds are sown. In a day or two the plants make their appearance. Air must be admitted every day, but with great caution, and the frame should be covered at night by mats. The plants should receive gentle watering of water, with the chill taken off.

When the plants have attained a little size, they are planted out to the part of the hotbed where they are intended to remain. They will require watering and careful airings in the daytime, and protection in the night.

The two subsequent sowings will not be found to be so difficult to manage.

A supply of small cucumbers, or gherkins, for pickling, may be obtained by digging a hole in the ground, filling it with hot dung, placing over this a layer of earth, planting in this cucumber seeds, and placing over all a hand glass.

PUMPKINS.

Pumpkin or gourd seeds should be sown (about an inch deep), in a hotbed, in the month of April. When they have attained a sufficient size, they may be planted out in the open air, taking the precaution to bury in the ground, where they are to grow, a considerable quantity of manure. They do very well if planted on the outsides of the hotbed.

VEGETABLE MARROWS.

The culture of these is identical with that of the last mentioned.

TOMATOES.

Tomatoes require to be sown, in a hotbed, in the beginning of April, and to be kept there until May, when they should be planted out in a south border. They require at first assiduous waterings. Even in warm situations, they cannot be reckoned upon to come to maturity every year.

EGG PLANT.

Its culture is the same as that of the tomatoe.

CAPSICUM.

Capsicum seeds are planted in the hotbed in March, and transplanted to the open ground in June.

MUSHROOMS.

A quantity of mushroom spawn may be buried, in little fragments, in and around the outsides, having previously covered these latter with mould. In this manner, an occasional dish may be got. For the benefit of any one desirous of having a regular mushroom bed, we extract the following directions from Rogers:—

"About Michaelmas is the general season for making mushroom beds (although it may be done all the year round). A quantity of the dung mentioned should be collected, and thrown together in a heap, to ferment and acquire heat; and as this heat generally proves too violent at first, it should, previously to making the bed, be reduced to a proper temperature, by frequently turning it in the course of the fortnight or three weeks, which time it will most likely require for all the parts to get into an even state of fermentation. During the above time, should it be showery weather, the heat will require some sort of temporary protection, by covering it with litter, or such like, as too much wet would soon deaden its fermenting quality. The like caution should be attended to in making the bed, and in finishing it.

"As soon as it is observed that the fiery heat and rank steam of the dung are gone off, a dry and sheltered spot of ground should be chosen on which to make the bed. The place being determined on, a space should be marked out, five feet broad, and the length (running north and south) should be according to the quantity of mushrooms likely to be required.

"On the space marked for making the bed, a trench should be

thrown, about six inches deep. The mould may be laid regularly at the side, and, if good, it will do for earthing the bed hereafter; otherwise, if brought from a distance, that of a more loamy than of a sandy nature will be best.

"Either in the trench, or if upon the surface, there should be laid about four inches of good dung, not too short for forming the bottom of the bed; then lay on the prepared dung, a few inches thick, regularly over the surface, beating it as regularly down with the fork. Continue thus gradually drawing in the sides to the height of five feet, until it narrows to the top, like the ridge of a house. In that state it may remain for ten days or a fortnight, during which time the heat should be examined towards the middle of the bed, by thrusting some small sharp sticks down, in three or four places; and when found of a gentle heat (not hot), the bed may be spawned; for which purpose the spawn bricks should be broken regularly into pieces, about an inch and a half or two inches square, beginning within six inches of the bottom of the bed, and in lines, about eight inches apart. After spawning the bed, if it is found to be in that regular state of heat before mentioned, it may be earthed. After the surface is levelled with the back of the spade, there should be laid on two inches of mould. That out of the trench, if dry and good, will do; otherwise, if to be brought, and a choice made, that of a kindly drain is to be preferred. After having been laid on, it is to be beaten closely together; and when the whole is finished, the bed must be covered, about a foot thick, with good oat straw, over which should be laid mats, for the double purpose of keeping the beds dry, and of securing the covering from being blown off. In the course of two or three days, the bed should be examined, and if it is considered that the heat is likely to increase, the covering must be diminished for a few days, which is better than taking it entirely off."

THE PORCELAIN AND POTTERY MANUFACTURES.

ARTICLE II.

HISTORY AND DESCRIPTION OF THE POTTERY DISTRICT.—THE POTTERY MANUFACTURE.

Having described in our first paper the materials and processes for making the finer ware, termed porcelain, let us now transfer our attention to the pottery and earthenware manufacture, associated especially with the Staffordshire district.

The district known as the Staffordshire Potteries, is a portion of the country about ten miles in length and two or three in breadth, lying a little eastward of the town of Newcastle-under-Line, and occupying an area of perhaps twenty thousand acres. It may be characterised as one long street from end to end, for the successive towns and villages are so near each other, and have gradually been so connected by rows of houses, that the eye glances from one to another with scarcely an appreciable interruption. The towns, townships, hamlets, and villages, are very numerous; but the most notable are Tunstall, Burslem, Cobridge, Hanley, Shelton, Etruria, Stoke, Fenton, and Lane End; and if we pass through these towns on the high road, we shall find on either side a continued string of potteries and porcelain works, so large and so numerous that one may almost wonder where a market can be found for the immense mass of articles produced there.

This, then, is the Pottery district; and on inquiring into its history, we shall find that the busy hive of potters has been accumulated there by two circumstances—the existence in the neighbourhood of mineral products indispensable to the manufacture; and the facilities which are always afforded when many men of one trade congregate in one place. The talents and energies of a Wedgwood would have created a manufacture anywhere; but when these were brought to bear in a district already distinguished for its manufactures, the spot could not fail to become a great centre of productive industry.

There are indications that the pottery art was exercised in Staffordshire in the time of the Romans; for many specimens of earthen vessels are occasionally dug up in the district, referable to no later period of English history. Whether, or to what extent, the manufacture was there carried on in the ages subsequent to the Roman occupation, can now hardly be answered. It will suffice to say that Burslem, the "Mother of the Potteries," exhibits proof that this manufacture has been carried on there for centuries. Before the time when Dr. Plot made his survey of Staffordshire in 1686, there were here and there kilns and ovens, with rude buildings covered with thatch. The manufacture of *butter-pots* seems to have been, in the seventeenth century, a kind of staple product at Burslem. Plot says that "the greatest pottery they have in this county is carried on at Burslem, near Newcastle-under-Line, where, for making their several sorts of pots, they have as many different sorts of clay, which they dig round about the town, all within half a mile distance, the best being found nearest the coal, and are distinguished by their colours and uses." He also tells us that at that time (1686) "the factors buy their butter by the pot, of a long cylindrical form, made at Burslem, of a certain size, so as not to weigh above six pounds at most, and to contain at least fourteen pounds of butter."

The wares made at that time at Burslem (then the only pottery-town in the district) were of a very rough and coarse kind; but a discovery made towards the end of the seventeenth century paved the way for great improvements: this was the use of salt in glazing pottery, apparently until then unused in this country. The incident is recorded thus:—At Stanley Farm, situated not far from Burslem, the servant of Mr. Joseph Yates was boiling in an earthen vessel a strong lixivium of common salt, to be used in curing pork. During her temporary absence the liquor boiled over, and some ran down the sides of the vessel, covering the surface with a liquid which on cooling appeared as a glaze. Mr. Palmer, a potter of the neighbourhood, being made acquainted with the fact, speedily availed himself of it, and established the manufacture of the common brown glazed ware. There were salt-beds in some of the neighbouring districts, and this led to the extension of the manufacture to spots still farther from Burslem.

About the year 1690, a very remarkable instance of the extension of the potteries near Burslem occurred. At that time the East India Company were in the habit of importing from the East "unglazed red porcelain" vessels, of a beautiful red colour and form, which had never been equalled in England on account of the want of the proper clay. It was discovered, however, that at Bradwell and Brownhills, near Burslem, a fine grained and beautifully tinted red clay could be procured; and this, together with an abundant supply of coals for the ovens, led to the establishment of a pottery at Bradwell by the Messrs. Elers, from Nuremberg. Here they made red porcelain unglaced tea-pots, simply of the fine red clay of the district; as also black or Egyptian porcelain, by adding manganese to deepen the tint. The brothers Elers seem to have been in advance of their neighbours, and to have taken extraordinary precautions to baffle curiosity. The servants employed were ignorant and stupid, and the thrower's wheel was turned by an idiot: each person was locked in the place where he was employed; and such were the precautions to preserve the supposed secret, that, previous to the workpeople retiring at night, each was subjected to a rigid examination. However, all their precautions were fruitless; for two persons, named Twyford and Astbury, succeeded in worming out the secret. The former got employment at the works; and by manifesting entire carelessness and indifference to the nature of the processes, he masked his real object, which was to find out all that was new in the operations at Elers' works. Of the other man, Astbury, the account handed down is very remarkable. Having assumed the garb and appearance of an idiot, with all proper vacuity of countenance, he obtained employment at the Bradwell manufactory, and received the cuffs, kicks, and jeers of his fellow-workmen in a manner accordant with his assumed character. He was put from one occupation to another; having apparently just sense enough to make him worth the pittance which he received. Meanwhile he lost no opportunity of

observing the processes and working apparatus; and on returning home each evening he formed models of the several kinds of implements, and made memoranda of the processes. He continued this practice for nearly two years, until he ascertained that no further information was likely to be obtained, when he availed himself of a fit of sickness to continue at home; and this was represented as very malignant, as a means to prevent any person visiting him. After his recovery, the Elers seemed to have a suspicion that he was too clever for them, and he was discharged: but they soon found that he had taken their secret with him; and they had the mortification to see the Burslem potters avail themselves of methods which they thought rested with themselves.

Such is the tradition. Those who have read much on the history of manufactures will call to mind many parallel instances, in which men have feigned illness or stupidity as a means of discovering processes otherwise kept secret. There may be a little colour of romance thrown over the story; but there is no reason to doubt the main points.

Thus step by step did the manufacture spread, the establishments increasing in number as new kinds of ware became introduced. Topographically considered, this extension travelled southward; for Burslem, the parent pottery-town, is nearly at the northern extremity of the district. Twyford and Astbury commenced manufactories at Shelton, about three or four miles from Burslem, and there carried on the red porcelain work, and the white ware glazed with salt. Some years afterwards, Mr. Astbury's name became connected with another singular adventure, by which another step was made in the progress of the manufacture. While on a journey to London on horseback, Astbury was compelled to seek a remedy for the eyes of his horse, which seemed to be rapidly going blind. The ostler of an inn near Dunstable burned a flint-stone till quite white, pulverized it, and blew a little of the dust into the eyes of the horse, by which they were made to discharge copiously. Astbury, having noticed the white colour of the calcined flint, the ease with which it was then reduced to powder, and its clayey nature when discharged in the moisture from the horse's eyes, immediately conjectured that it might be usefully employed to render of a different colour the pottery he made. On his return home he availed himself of his observation, and soon obtained a kind of ware exhibiting marked improvement on the pre-existing kinds. Mr. Porter remarks, that "it could have been no common mind which led Astbury to the long-continued pursuit of his object by means so humiliating; and which also enabled him, on the occasion just related, to seize upon a fact thus accidentally presented, and which, although of high importance to his art, might have passed unheeded before the eyes of many a commonplace manufacturer."

We next come to the era of Mr. Josiah Wedgwood, who was to the pottery manufacture what Watt was to the steam-engine and Arkwright to cotton-spinning—its greatest improver. The pottery district of Staffordshire owes to this remarkable man a large measure of its wealth and of its commercial importance. We find various items in the history of the potteries during the early half of the last century, in which the names of Mr. Aaron Wedgwood, Mr. Thomas Wedgwood, and Mr. John Wedgwood are mentioned: these were potters, apparently in rather humble circumstances, in and near Burslem. Thomas was said to have been an excellent 'thrower' at the wheel, while John was a skilful 'fireman' in the glazing department; and both left their father, Aaron Wedgwood, to set up for themselves in Burslem. It was about a century ago when the two brothers established themselves; and they soon created a large business by the industry and sagacity with which they sought out the most improved clays and glazes for their wares.

Josiah Wedgwood, the most distinguished of the family, was the son of Thomas, and was born in Burslem in 1730. His early education was very limited; and at the age of eleven he worked for his father as a 'thrower.' An old man, many years afterwards, used to relate that he had been engaged by Thomas Wedgwood to make 'balls' (as the lumps of clay are called) for the two sons, Josiah and Richard, which they, as throwers, formed into vessels, the two youths being seated in the two corners of a small room. Some years afterwards, Josiah Wedgwood joined in partnership with one Harrison, of Newcastle, and afterwards with a Mr. Whieldon; but he appears to have returned to Burslem about 1760, and to have there set up in business on his own individual resources. He established two manufactories at Burslem, where he made knife-handles, green tiles, imitative tortoiseshell and marble plates, white stone-pottery, and other articles. He next turned his attention to 'cream-coloured' ware, for which he had soon such a demand that he built a third factory. After a time Wedgwood opened a warehouse in London, for the management of commercial dealings, and as a depot for articles contributory to that remarkable style of manufacture which he soon struck out. He collected vases, busts, cameos, intaglios, medallions, seals, and other works of art; and began to exercise his ingenuity in imitating them in pottery or porcelain. His imitations of Greek, Roman, and modern Italian productions were so exquisite, that he gained renown throughout Europe; and men of taste were accustomed to visit Burslem to see the operations of his establishment. The Barberini or Portland vase will always be closely connected with the name of Wedgwood, as showing what the potter's art can effect. This celebrated vase being put up to auction, Wedgwood was very desirous of buying it as a pattern from whence to manufacture copies. The Duchess of Portland 'bid' for it; but Wedgwood bid against her so pertinaciously, that it attracted the Duke's attention; who, when he knew the cause of Wedgwood's solicitude, offered him the loan of the vase for an indefinite period, if it would terminate his biddings. He did so; and the vase was sold to the Duchess for nearly two thousand guineas. Such is the account given by Mr. Shaw. Wedgwood thereupon employed the finest modellers and the most talented workmen in every branch, through whose aid he produced fifty copies of the vase, which he sold for fifty guineas each: as a commercial speculation it failed, but it raised his name to a high pitch of eminence as a tasteful manufacturer.

Meanwhile he did not neglect the more useful varieties of earthenware. He presented to Queen Charlotte some specimens of painted cream-coloured ware; which so pleased the Queen, that she ordered a complete table-service of the same kind: the pattern selected was thereafter known as the 'Queen's pattern,' and the ware as the 'Queen's ware,' while Wedgwood himself received the appointment of 'Potter to the Queen.' He next invented a much-admired ware known as Jasper-ware. This was a beautiful white ware, capable of receiving rich and pure colours on any part of its surface, by which striking imitations could be produced of various kinds of ancient works of art. A kind of black ware, called Black Egyptian, was also by him applied to the making of busts and figures.

By the year 1777, a canal, the 'Grand Trunk,' had been opened for the conveyance of the pottery from the Staffordshire district to the two great northern ports of the kingdom, Liverpool and Hull. But at the time Wedgwood commenced his labours, the means of conveyance were miserably insufficient. In some instances the flint used in the manufacture was carried from the mill where it was ground to the manufactories by men; in other instances, by horses, which carried tubs, holding two pecks each. The chapmen, or dealers, kept gangs of horses which carried small crates; and in these crates was stowed the ware, to be carried from place to place, and exhibited to purchasers. Afterwards, when the roads became improved, under the provisions of an act of parliament, carts and waggons were substituted for pack-horses; and persons travelled from place to place for orders, instead of the goods being hawked about for sale. At length the Grand Trunk Canal was boldly projected by Brindley; Wedgwood advocated it earnestly, and, as it is said, turned up the first clod of earth with his own hands, near his works at Burslem.

When the canal opened a communication between the potteries and various parts of England, Wedgwood removed from Burslem, and built a large manufactory on the banks of the canal, near which he also built an elegant house for himself, and a village of neat dwellings for his workpeople, calling the whole *Etruria*, after the ancient Italian state which produced such beautiful specimens of earthen vases, &c. Here Mr. Wedgwood continued to reside till his death; and here his

descendants still carry on the business which he founded. This handing down of manufacturing establishments from father to son has been very observable in the Potteries.

Beyond this point we need not trace the history of the Potteries. The celebrity of Wedgwood and the exertions of other manufacturers, together with the gradual introduction of printed ware, porcelain, &c., raised the Potteries to a commercial rank which they have ever since maintained.

Let us see, then, what kind of a district this is, which has, *par excellence*, acquired the name of "The Potteries;" a name so distinctive, that when the parliamentary boroughs were remodelled in 1832, the franchise was given to the whole of this district as one borough, since which time there has been an "honourable member for the Potteries," although, nominally, the borough is designated by one of its towns, Stoke. Supposing a visitor to approach the Potteries by the Grand Junction Railway, and to pass through Newcastle-under-Line towards Stoke, he will arrive at the district about midway between its two extremities: Tunstall, Burslem, Cobridge, Hanley, and Shelton will be to the north; Fenton, Lane Delph, Lane End, and Longton will be southward; and to whichever direction he may turn, he will not be slow in observing that the towns consist mainly of small houses, in streets branching out from the highroad, which runs nearly north and south. There are not many handsome buildings, and still fewer monuments of antiquity; but, on the other hand, there are very few indications of squalor and wretchedness. Nearly every person throughout the district lives directly or indirectly by the manufacture of pottery; and as this branch of manufacture is subject to less fluctuation than most others in the north, the instances of extreme poverty are rare. There is no living in cellars and hovels; nor is there any congregating of twenty or thirty families in one house, as some of our large towns exhibit: the houses are small and humble, it is true, but they exhibit indications of comfort which show that a large amount of wages must be distributed weekly among the seventy thousand inhabitants of the district.

Pottery is not a domestic manufacture; that is, it is not carried on in the houses of the workmen or in small shops; it is conducted in large manufactories; so that the three features which the district mainly exhibits are—the manufactories themselves, the private dwellings of the proprietors, and the streets of small houses inhabited by the workpeople. The manufactories are distinguishable by large, lofty, dark-coloured structures, shaped somewhat midway between a sugar-loaf and a bee-hive; these are the ovens in which the ware is baked; or rather, they are 'hovels,' which surround the ovens, and within which the men stand to attend to the ovens. Every establishment has these 'hovels,' and the extent of the operations is in some degree indicated by the number of them. Frequently, in walking along the highroad, we may see a handsome private dwelling, with hovels and other buildings behind it; in such case the probability is that the house is inhabited by the proprietor of the works. If a stranger ask a question concerning these manufacturing premises, he will be told that it is "Mr. So-and-so's bank"—the pottery-works being known technically as 'banks'—why, we cannot say. "Whose premises are those yonder?" "That's Mr. Wedg-'ood's bank at Trury," was the reply; for Etruria is stripped both of its beginning and its end by the workpeople.

The village just named, Etruria, is situated a little out of the main road through the potteries. It is in the road from Newcastle to Hanley, and consists almost entirely of one street, containing about a hundred and fifty houses; these were built by Mr. Josiah Wedgwood, and are occupied chiefly by persons employed in the neighbouring works. A singular uniformity is exhibited by these dwellings, both in their outward appearance and their interior arrangements. The street-door opens directly into the front parlour; in fine weather the door is always open, and, in almost every case, the first object which meets the eye of a passer-by in each house is a chest of drawers, immediately opposite the door. Now, without discussing the question how far a chest of drawers is a test of respectability, it is always observable that many comforts are collected around a family which possesses this article of furniture; it shows that there are "Sunday clothes" to be taken care of, and a decent pride in their preservation. The windows, too, one and all, are decked with flowers, planted in pots which would put to shame the coarse red flowerpots of a London window-sill.

There is one external mark by which the pottery operatives are to be known, all the way from Tunstall to Lane End—in the banks on the road, and at the doors of their own houses. This is the small, drab-felt, close-fitting, hemispherical skull-cap, which is worn by most of the men and boys. The manufacture of these caps is largely carried on at the neighbouring town of Newcastle; and they are worn because they are cheap, and because, as it is asserted, they "keep the head warm in winter and cool in summer."

At all the various towns there are banks, or pottery manufactories, on a very large scale, as well as others of a smaller size. In some of these establishments the very finest kinds of porcelain are manufactured; in others only the common earthenware: while others again combine both classes of productions. At Lane End, besides a few establishments of the higher class, there is a very large number of minor banks, where the commonest kinds of stone and yellow ware are produced, and whence the hawkers and street-dealers all over England obtain their supply. Near here, too, as well as in many other parts of the Pottery district, there are coal-pits, from which is procured, for six or eight shillings per ton, an abundant supply of coal well fitted for the pottery ovens, although not equal to the South Staffordshire coal for open fires. At a little village near Tunstall, all the cottagers seem to have their "coal-cellars" in the open air; for the coals are thrown down in the front of each house by the side of the door, and thence carried in as wanted.

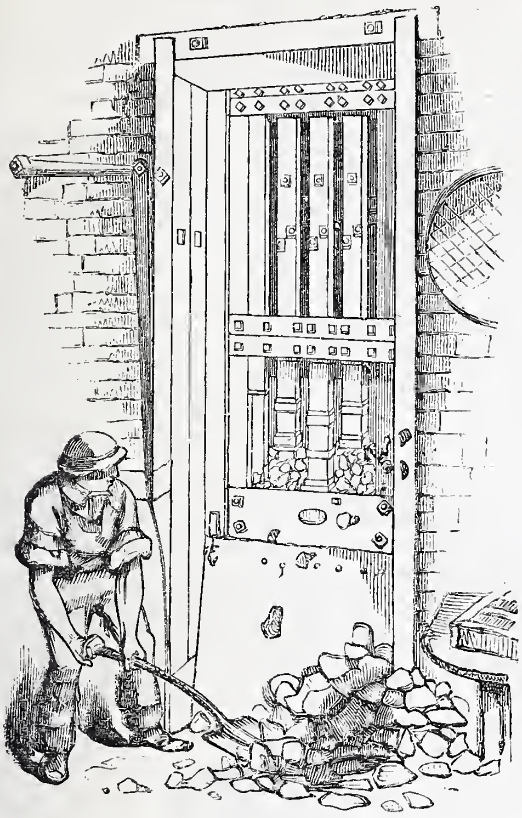
The structures which can correctly be termed "public buildings" are but few in the Potteries. Churches, chapels, market-houses, and town-halls, are the principal. In a small street in Shelton, there is a neat building appropriated as a "Pottery Mechanics' Institution." It was established by a few noblemen and some of the chief potters of the district many years ago, and has a small lecture-room, a library, and class-rooms for various branches of instruction.

Such are a few of the external characteristics of the district. Let us next witness the internal. In some of the larger of these banks (employing nearly a thousand men each) there are numerous groups of buildings called squares, designated according to the purpose to which they are applied. One, for instance, is the 'dishmakers' square;' that is an open area surrounded by buildings, in which the makers of dishes work. Then there are the 'plate square,' the 'saucer square,' the 'coloured-body square,' the 'printers' square,' &c., each comprising a court or area encircled by buildings. One, too, called the 'black bank,' affords an illustration of the nomenclature spoken of before; this being a bank, or series of workshops, where black ware is made. Besides these are the numerous biscuit-ovens, glaze-kilns, annealing-ovens, &c. Most of the large works are contiguous to the Grand Junction Canal, and exhibit a large area, occupied with the crude material for manufacture; such as the *chert*, for the floor of the grinding-mills; the *gypsum*, or *sulphate of lime*, to make plaster moulds for casting; the *flints* from Gravesend and Northfleet, as one material for pottery; the Staffordshire *marl*, for forming the seggars, or fire-cases; the Devon, and Dorset, and Cornwall *clays* and *stones*, employed in the manufacture; and the *coals* with which the ovens and kilns are to be heated. It is a curious circumstance, that at the present day the Staffordshire clay is not employed for any of the pottery: it has been entirely superseded by the clays of other districts, and is now only used to make the seggars: it is a kind of marl found interstratified with the coal, and is easily procured.

We now proceed to such parts of the manufacturing details as have not been described in the former article, and rather relate to earthenware than porcelain. Flint and a few kinds of clay form the main ingredients of all the numerous varieties of pottery and porcelain, and are made fit for the potter's use by nearly the following processes:—The flints, brought from Gravesend in irregularly-shaped pieces, are placed in a kiln, shaped somewhat like a lime-kiln, where they are

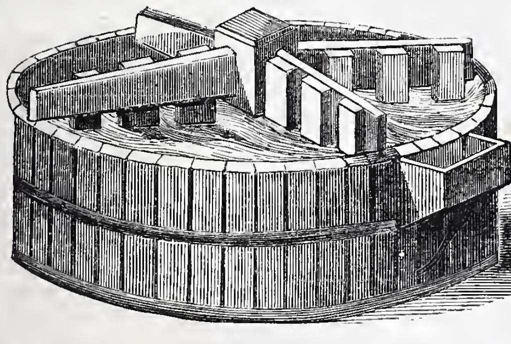
stratified with layers of small coal. Heat is applied, and the flints are burned or calcined to a white colour, in which state they are more easily broken than before. These pieces are then pounded to still smaller fragments by the 'stampers' represented in the cut (fig. 1), and which act in a

Fig. 1.



curious manner. These stampers are perpendicular pieces of wood, loaded with iron, and fall upon or into a box, whose bottom consists of a strong iron grating; they are raised alternately by machinery connected with a steam-engine, and made to fall heavily upon the pieces of calcined flint, which become thereby broken small enough to fall through the iron grating. The flinty fragments are then ground to a perfectly fine state in a large vat or vessel, designated the 'mill' (fig. 2).

Fig. 2.



This is a circular vessel, twelve or fourteen feet in diameter, having four arms extending from its centre, which arms carry round what, in another form of the machine, would be the upper millstone. The bottom is lined or paved with Welsh 'chert,' a species of flint; and the arms carry round large heavy blocks of the same substance, by which the calcined and crushed flint, after being thrown into the vessel and covered with water, is found to be of a consistence nearly as fine as cream.

The Cornish clay is partially prepared in Cornwall (as formerly described) from a kind of decomposed granite, called Cornish stone, which is ground and washed, and the lighter argillaceous particles allowed to flow into channels and pits, where a sediment forms, which is afterwards made into cakes, and then barrelled for shipment to Liverpool. The Dorset clay receives hardly any preparation before it arrives at the Potteries. The sulphate of lime, from which the plaster of Paris for the moulds is to be produced, is first broken small, then ground fine in a mill similar to a flour-mill, and placed in a trough formed of fire-brick; heat is then applied, by which the sulphate loses its crystalline form, and assumes the well-known appearance of plaster of Paris.

All these operations are preparatory to the 'slip-making, the process whereby the clay is brought into the state fit for the potter's use. Whether clay be for the finer kinds of porcelain or for earthenware the arrangements for 'slip-making' are analogous in their character. The materials travel downwards, from one level or stage to a lower one, and then to a lower one again, in the course of preparation. Each kind of clay and flint is beaten up, in a distinct vessel, with water, into a sort of cream, by means of rotating arms worked by machinery. The proper thickness of this cream is estimated by the number of ounces which a pint of it will weigh, each kind having a recognised weight, known by experience to be best fitted for the object in view. These different creams then flow into large tanks, and from thence along troughs into other tanks, where they are mixed together; gauge-marks being used to afford a guide as to the quantities mixed together. Taps or valves are provided, through which the mixture fails into sieves of hard-spun silk, which have a reciprocating motion given to them by machinery: the fineness of this lawn (for the best porcelain) is such, that there are three hundred threads to the square inch: and the cream thereby becomes reduced to an extremely fine state by the time it has passed downward from the coarser to the finer sieves.

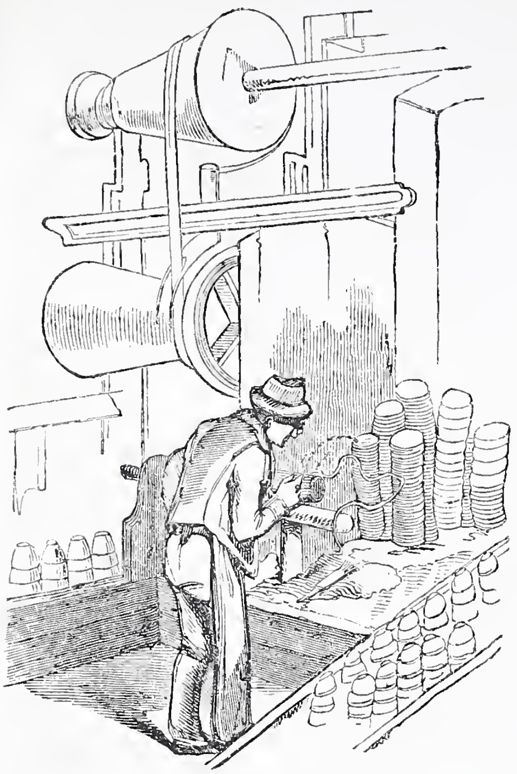
This mixture, then, is called 'slip,' and we follow this slip to the 'slip-kiln,' a remarkable and very long building. This place, as formerly described, consists of a low room, having on either side shallow slip-kilns, and a passage down the middle. The kilns are merely open troughs, sometimes fifty or sixty feet long, formed of fire-brick, and heated with flues underneath. Here the 'slip,' or clay-cream, remains exposed to heat for twenty-four hours, by which it evaporates to the stiffness of clay. Or the same effect may be produced by filtration, as described and illustrated at p. 613, Vol. II.

One more process is necessary before the clay is ready for the potter. When taken from the slip-kiln, it is not sufficiently smooth and homogeneous, but requires a kind of annealing or kneading. This used, in the early history of the manufacture, to be performed by laborious manual operation; but a very ingenious and effective kind of apparatus is now employed for this purpose. It consists of an inverted conical machine, down the centre of which runs an axis provided with knives or cutters. The clay, being put into this machine, is cut and pressed so as to become thoroughly amalgamated, and finally forced through an aperture in the bottom of the machine.

The clay, being thus prepared, is transferred to the 'plate-makers' square,' the 'dish-makers' square,' the 'throwing-room,' or to any of the numerous workshops where the potters are employed. How the general process of 'throwing' is effected, by which the greater number of earthenware vessels are made, we have already given a description, and also of the mode in which the 'handle-maker' proceeds. We may therefore pass over these operations here, and notice one or two others. The 'turner,' it will be seen from the cut on next page (fig. 3), works at a lathe in a manner very similar to the turner in wood: the 'thrown' and partially dried vessel is fixed to the chuck of the lathe, and by means of iron and steel tools of various shapes, the turner gives symmetry of form and smoothness of surface to the vessel.

Plate-making, dish-making, and saucer-making, constitute very large departments of the manufacture, and in such works

Fig. 3



as are now engaging our attention, each department is wholly distinct from the others. One of the plate-makers is represented

Fig. 4.

in fig. 4, which will illustrate the following description of making a plate:—Beneath the workman's hands is a vertical pillar, on the top of which is a horizontal wheel bearing a reverse copy of a plate made in plaster of Paris; that is, the upper surface is the same size and shape as the inside or face of the plate which is to be made. The workman, having beaten out a piece of clay to nearly the required thickness and diameter, lays it upon the plate mould, places this mould on the horizontal wheel, and bids his attendant (a lad) set it into rotatory motion by means of a winch-handle. While the mould and clay are rotating, he presses the latter down upon the former with a wet sponge, and then proceeds to give the contour to the upper surface of the clay (to form the *bottom* of the plate) by means of gauges, ribs, or profiles. The plate is thus formed in a very short time; the plaster mould giving the one surface, and the gauge the other.

Dishes, saucers, and all flat vessels, of which one side is scarcely seen, are made in a similar manner, the least important side, generally the bottom, being formed by means of the gauges or patterns, while the surface which is to be visible is shaped by means of the plaster-mould. The plates, &c., are not removed from their respective moulds directly they are made; they are put into drying-stoves, mould and all; then taken out and trimmed smooth by passing the profile-gauges again over them; again stoved, and then separated by the contraction of the clay. But when both surfaces of a flat vessel, such as in the more ornamental kinds of porcelain, are to be visible, the vessel is generally moulded on both sides by a more complicated process.

How the ware is brought from the 'green' state to the 'biscuit' state, was sufficiently explained in the former articles, and renders any detailed description unnecessary here. The manufactured vessels, whether thrown at the wheel, or pressed, or cast in moulds—whether of earthenware or of porcelain—are placed in seggars, or fire-cases, as a means of protection from smoke, and these seggars are placed in the biscuit-ovens which are so numerous at these works.

The 'biscuit warehouse,' in which all the ware is temporarily deposited after being 'fired' in the ovens, is very striking to a stranger, from its large size, and the enormous piles of ware always lying there. In one factory we have seen as many as four thousand dozens of common white basins, all of one size, and all piled in one pyramidal heap in the biscuit warehouse!

The manner in which earthenware is commonly decorated, is strikingly different from that adopted with respect to porcelain. The decorations on porcelain, as have been pretty fully explained, are produced by painting, with camel-hair pencils, various devices on the porcelain, the paint or pigment being formed of mineral colours, which are afterwards made to adhere permanently to the porcelain by the heat of the annealing-kiln. In pottery, however, a cheaper and more expeditious mode is adopted. One kind is called gold or silver *lustre-ware.* To produce the metallic lustre on the surface of this ware, certain metallic oxides are mixed up with essential oils to the consistence of a paint, and then applied with a brush over the surface of the vessel: the heat of a kiln afterwards dissipates some of the component ingredients, and leaves the metallic lustre visible; but the metals employed are merely substitutes for gold and silver, not the costly metals themselves.

Another variety, called 'dipped-ware,' receives its decorations in a manner so remarkable as to form one of the most curious operations of a pottery. It is a cheap kind of ware which is thus ornamented, and may be known by the fanciful but rather indefinite devices on the surface, in three or four different colours; the device being raised somewhat above the general level of the surface, but similar to it in texture. After the vessel has been turned, it is fixed to a wheel, which is made to rotate while the workman effects the operation. We shall suppose that the vessel is to have a device in three colours, brown, yellow, and blue: in such case the workman prepares three kinds of clay, coloured to the proper tint, and brought to the consistence of paste or cream by admixture with water. A portion of these three he puts into a kind of funnel having three compartments, so that all three remain separate, and yet flow out of three adjoining apertures at the bottom simultaneously. This funnel the workman holds over the vessel while revolving, in such a manner that a little stream of tri-coloured paint shall drop upon it, and form bands, stripes, spots,

curves, or spirals, according to the manner in which the funnel is held, and the velocity with which the vessel rotates. The three colours are contiguous, and flow in a united stream from the funnel; yet they are perfectly distinct in their position in the vessel. The vessel, it will be understood, is on its side, and rotating on a horizontal axis. The quickness with which this proeess is effected is quite astonishing, and the whole affair demands singular dexterity in the workman.

Perhaps, in the whole range of the pottery manufacture, there is no kind of decorative operation which has been more generally approved, or which has tended more to give neatness to the appearance of the manufactured articles, than that of 'blue printing,' or the transference to the ware of a device previously printed on a piece of paper from an engraved copperplate. Before the introduction of this kind of ware there were two kinds, called 'blue-painted' and 'black-printed' wares: the former having merely a small border or edging round each vessel, painted in blue colour with a pencil; and the latter having a device transferred to the glazed ware by a kind of printing. But both were in time superseded by the method of 'blue printing.'

The arrangements for 'blue printing' are simply as follow:—The designer in the first place draws a design, corresponding in size to the size of the vessel to be printed. In the early stage of the system, no fine lines were introduced into the design; but coarse unmeaning patterns, such as the 'willow' pattern, were alone employed. By degrees, however, a better taste prevailed, and landscapes and other pleasing subjects were introduced. The design, when finished, is given to an engraver, who engraves it on a flat copperplate in the usual manner. From the plate so engraved, impressions are taken upon a peculiar kind of thin paper, made expressly for this purpose. The colour for the impression is a mixture of certain metallic oxides with oil, and is brought to the thickness of a cream. The engraved plate is placed upon a flat stove; and, when heated, the printer rubs the ink well into the device, as seen in fig. 5. With a knife he then scrapes off the super-

Fig. 5.

fluous ink from the surface, and rubs the plate quite clean, leaving ink only in the engraved device. Meanwhile the paper has been moistened in soap and water; and an impression is then taken by means of a small roller-press.

Immediately that the printed paper is ready, it is handed to a woman called a 'transferrer,' who, in the manner next sketched (fig. 6), lays it down upon the plate or other earthenware vessel which is to be printed. Sometimes it can be put on in one piece; while at other times it is cut into a few pieces by another female, and then adapted to the various curvatures of the vessel. The transferrer next takes a kind of rubber, formed of

Fig. 6.

a roll of flannel wrapped round the end of a stick, and rubs the paper very forcibly down upon the vessel, the coloured surface being next to the vessel; this rubbing is so violent, that if the paper were not of a tough quality (though thin) it would be worn into holes. The ware, being in the porous 'biscuit' or unglazed state, imbibes the colour from the paper. The vessel is immediately handed to another female, who immerses it in cold water, and washes off all the paper from the surface. It is then seen that the ware has imbibed the colour so intimately, that the washing away of the paper has not removed it from the ware: the device is perfectly transferred. The ware is placed in a kiln, to drive off the oil from the ink; and the printed vessel is then ready for the process of glazing. Thus is effected the decoration of a kind of ware, the introduction of which, to use the words of Mr. Porter ('Treatise on Porcelain'), "has added materially to the decent comforts of the middle classes in England, and has, more than any other circumstance, contributed to the great extension of our trade in earthenware with the continent of Europe."

As it is always valuable to know what intelligent foreigners think of us and our manufactures, it may be well to close this article with a quotation from M. Kohl's recent work on England:—"If we compare the common earthenware of England with that of the French and Germans, or of any other nation, it appears not only excellent in quality, but also highly ornamented and unsurpassingly beautiful. The common French and German earthenware is comparatively ugly, coarse, and misshapen. On the other hand, English porcelain, as I have already remarked, particularly those articles in which elegance and beauty are the main points aimed at, are far behind those of the Continent. I believe there is something characteristic of the English in this. In articles of ordinary use, the English seem better than we to know how to combine excellence of quality with outward elegance and beauty; whereas, in those articles in which grace and beauty alone are to be kept in view, the English are never equally successful." It is with the ex-

press view of elevating the taste of manufacturers in these and similar respects, that "Schools of Design" are being established in the manufacturing districts.

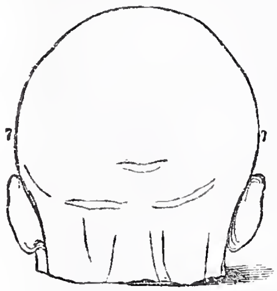
THE SCIENCE OF PHRENOLOGY.

CHAPTER VII.

ORDER I.—FEELINGS.

GENUS I.—INFERIOR PROPENSITIES.—(*Concluded.*)

7. SECRETIVENESS.—The organ of Secretiveness is situated in the centre of the lateral portion of the brain, just above Destructiveness and below Cautiousness. Dr. Gall gives the following account of its discovery. In early youth he was struck with the form of the head of one of his schoolfellows, who, with amiable dispositions and good abilities, was nevertheless distinguished by peculiar traits of cunning and concealment. He observed the same in another schoolfellow, but who, to look at, and judge of from the physiognomical expression of his countenance, appeared all sincerity and open-heartedness. The Doctor, nevertheless, observed that he was a great cheat—that he imposed on every person he came in contact with, whether schoolfellows, teachers, or even his own parents. Continuing his observatious, he next examined the head of one of his patients who had died, and during his life was supposed to be a very honest man, but was discovered afterwards to have cheated both his acquaintances and his relatives out of large sums of money. In all these persons, the portion of the brain we are now illustrating presented an extra large appearance.



"At Vienna," observes Dr. Gall, "I was often in company with a physician of uncommon attainments, whose character for cheating rendered him universally despised. Under pretence of dealing in objects of art, and of lending on pledges, he fleeced all who put any confidence in him. He carried his trickery and cheating so far, that the government warned the public, through the newspapers, to beware of him; for he had practised his arts with so much dexterity, that he never could be legally condemned. He frequently told me, with an air of sincerity, that he knew no greater pleasure, no more exquisite enjoyment, than that of duping people, and especially those who distrusted him most. As this physician's head was also very large at the temples, I was naturally impressed with the idea, that the essential quality of this character, cunning, is a primitive one, aud is manifested by a particular organ of the brain." *

It must be remembered that almost all the discoveries of Gall were from organs in a state of excess or abuse; and the phrenological nomenclature, imperfect as it still is, was much more faithfully expressed by the observations and corrections of his colleague, Dr. Spurzheim. No one power of the mind ought to be considered as baneful or injurious. *There is no such thing as a bad organ.* Cunning is an abuse of the organ of Secretiveness. But Secretiveness, in the exercise of its legitimate functions, is the origin of prudence, tact, skill, and circumspection; and it is indispensable for the regulation of our conduct towards each other. Of this we can produce the most unexceptionable authority. "Behold, I send you forth as sheep among wolves; be ye therefore prudent as serpents, and harmless as doves." Our Saviour made use of this comparison, that we might not bring ourselves into difficulty from a want of that necessary precaution by which our success in life is so frequently determined. In giving his disciples this advice, it was the same as admonishing them that they would have many enemies to encounter, which would require the exercise of all their prudence to overcome, and he chose the serpent as an apt analogy of this prudence. But there is another reason, which seems to have escaped the notice of most theologians. The perfection of the human character arises from the combined perfections of the animal referred to. Certain it is, that the life of man is a compound life, made up of an indefinite variety of affections and thoughts, and hence we may conclude that man will be more perfect as the variety is more extended; we may, therefore, not only say, "be wise as serpents, and harmless as doves," but "be strong as lions, playful as lambs, cheerful as larks," &c., &c., and endeavour to unite in ourselves the distinct excellencies of all the inferior creatures, while we avoid their defects; in other words, exercise all our propensities without abusing them.

* Gall's Works, vol. iv., pp. 119, 120.

Cardinal Perron says that the serpent is an excellent symbol of cunning, because it never carries its head directly before its body to the place it is desirous of reaching. In this it resembles a cunning man, who never betrays his intentions by his words or gestures.

But Secretiveness in excess manifests itself externally, or by a natural language, in a variety of ways. When you see an individual taking a side glance, and working his head round *a la Grimaldi*, you may be sure the possessor has very large Secretiveness. Observe persons whose heads are very prominent at the sides, and flattened on the top, and you will always find them false, artful, perfidious, venal, vacillating, and hypocritical. Such persons overwhelm you with politeness, and deafen you with flattery; they make you feel at home with them, that they may unsuspectedly lay their plots against you, and the more easily work your ruin. Sir Walter Scott faithfully delineates the natural language of this organ in his fourth canto of the Lord of the Isles, when Cormac Doil is introduced:—

> "For evil seem'd that old man's eye,
> Dark and designing, fierce, yet sly:
> Still he avoided forward look,
> But slow and circumspectly took
> A circling, never-ceasing glance,
> By doubt and cunning mark'd at once,
> Which shot a mischief-boding ray
> From under eyebrows shagg'd and grey."

Perhaps there never was a more complete exemplification of Secretiveness in excess than in the person of the late Tallyrand. He was so extremely astute, that he contrived to keep in power even under the most oppositely dispositioned sovereigns.

A lady once asked him to write his name in her album. His gallantry could not refuse, and he began to write a verse. "Hold!" exclaimed the lady, "it may be very well for inferior persons to write verses, but the name of Tallyrand alone is enough to appear in my book. It is fame." He fixed his keen eyes on the supplicating fair one, and wrote his name, but wrote at the very top of the page. The anecdote spread, and all Paris laughed at the happy evasion of perhaps seeing his name in a few days signed to a bill of ten thousand francs. Here there was a mixture of extreme Secretiveness, associated with Love of Approbation. No one, even among the fastidious Parisians, could question the good breeding of Tallyrand. He who does not practise good breeding, will not find himself as the object of good breeding by others. Good breeding is founded on the dissimulation or suppression of such sentiments as may probably provoke or offend them with whom we converse; to do this effectually, Secretiveness is indispensable.

Where Secretiveness predominates over all the other powers, the individual's sole delight is in plotting. Dr. Johnson mentions that Pope took so great a delight in artifice, that he endeavoured to attain all his purposes by indirect and unsuspected methods. He practised his arts on such small occasions, that Lady Bolingbroke used to say of him, in a French phrase, that he played the politician about cabbages and turnips.

Mr. Bulwer is most accurate in his definition of the charac-

ter of Lord Vargrave, as a personification of Secretiveness in excess. "He loved intrigue for intrigue's sake. Had it led to no end, it would still have been sweet to him as a means. He loved to surround himself with the most complicated webs, to sit in the centre of a million of plots. He cared not how wild some of them were. He relied on his own ingenuity, promptitude, and habitual good fortune, to make everything he handled conducive to the purpose of the machine, self."*

On this organ Dr. Spurzheim remarks, that it gives the propensity to conceal, without determining the object or the manner of concealing. It disposes to be secret in thoughts, words, and deeds. By its influence, the fox is careful not to be observed; the dog hides the bone he cannot pick; and the cunning man conceals his intentions, and sometimes professes opinions opposite to those he really entertains. It may be applied in an infinite number of ways, and employed under many varieties of circumstance and situation. If not directed by justice and the other moral feelings, it disposes to dissimulation, intrigue, duplicity, hypocrisy, and lying. It finds pleasure in all kinds of underhand doings and clandestine manœuvres. Whenever concealment interferes, be it for good or for evil purposes, this feeling dictates the course pursued.

8. Acquisitiveness.—Acquisitiveness is situated at the anterior inferior angle of the parietal bone. In our description of the organ of Combativeness, we related the manner in which Dr. Gall discovered it. His discovery of this organ originated in the same circumstances. At these meetings, some of the company accused others of various acts of petty larceny, who seemed to exult at the adroit manner in which they plundered others. They invariably were very largely developed at the particular parts now under review. Others, in the same company, manifested the strongest abhorrence at such base conduct, and in them the same parts were sometimes flat and even hollow. Dr. Gall had also an opportunity of examining the head of a boy, 15 years of age, who was confined in the house of correction, and whose propensity to steal was so inordinate, that, at that early period, he had been condemned to imprisonment for life. In his portrait, given in Dr. Gall's large work, the lateral region of the head is remarkably distinguished by a prominence, which is now established as the seat of the organ.

The following cases are extracted from Dr. Gall's works, vol. iv., p. 131:—

Victor Amadeus I., King of Sardinia, was in the constant habit of stealing trifles.—Saurin, pastor at Geneva, though possessing the strongest principles of reason and religion, frequently yielded to the propensity to steal.—Another individual was from early youth a victim to this inclination. He entered the military service, on purpose that he might be restrained by the severity of the discipline; but having continued his practices, he was on the point of being condemned to be hanged. Ever seeking to combat his ruling passion, he studied theology, and became a capuchin; but his propensity followed him even to the cloister. Here, however, as he found only trifles to tempt him, he indulged himself in his strange fancy with less scruple. He seized scissors, candlesticks, snuffers, cups, goblets, and conveyed them to his cell.—An agent of the government at Vienna had the singular mania for stealing nothing but kitchen utensils. He hired two rooms as a place of deposit: he did not sell, and made no use of them.—The wife of the famous physician, Gaubius, had such a propensity to pilfer, that when she made a purchase, she always sought to take something. She was always accompanied by a servant, either to prevent or compensate for her thefts.—Lavater† speaks of a physician, who never left the room of his patients without robbing them of something, and who never thought of the matter afterwards. In the evening his wife used to examine his pockets: she there found keys, scissors, thimbles, knives, spoons, buckles, cases, and sent them to their respective owners. —Moritz, in his experimental treatise on the soul, relates, with the greatest minuteness, the history of a robber, who had propensity to theft in such a degree, that, being "*in articulo mortis*," (at the point of death,) he stole the snuffbox of his confessor.

In all these cases, there can be no doubt but the brain was in a diseased state; for there was, at least, in most of them, no apparent motive of appropriation. The mode of treatment with such persons should have been the same as that of lunatics. In the case of juvenile thieves, they should not be sent to prison, but to an establishment where the object should be to reform them, and this on the commission of the first offence. When prepared by moral and religious training to lead a regular life, they might be restored to society, at first under strict surveillance. At each relapse, however slight, the penalty should be increased, and not until numerous relapses should they be for ever excluded from society. Should they be found incorrigible, they should be treated as lunatics, and confined for life, under proper restraint, but yet with such means of relaxation and exercise as might be proper for the preservation of general health. Alas! how far are we yet from such a mode of treatment in this country, where, almost daily, they prevent the penitent offender from returning to the paths of virtue! On discharge from prison, who will receive him? what house of refuge is open to him? None. He is forced to support his existence by banding with criminals whom society has rejected.

The necessity of adopting curative means in cases of juvenile offenders, and the injustice of inflicting punishment where this has been neglected, has been admirably illustrated in a work entitled "Old Bailey Experiences," from which I extract the following letter; whether written in irony or in sober truth from the supposed culprit, it is equally deserving attention:—

"I was born in Dyott Street, in the city of London. I never remember my mother; but my father's companions sometimes spoke of her, as one who had been transported for passing bad money. My father used to look gloomy and sorrowful when she was mentioned, and never recovered without a glass of liquor; some people said she died broken-hearted in gaol, but I never heard the truth of it. In our street, he who thieved the most cleverly was the most admired, and the only disgrace that could be incurred was the shame of detection. I sometimes, at the end of it, saw people ride past in fine coaches, and these, I supposed, had robbed still more successfully. I knew nothing, and was taught nothing but to steal; and I practised my art with an industry which I thought most laudable. I have heard of God, of hell, and the devil; and they once told me when the bell tolled at St. Giles', that people went there to pray that they might go to heaven, but I saw nobody who seemed to believe this, and I thought these words, like many others, were only useful to swear by. The only thing I was taught to fear was a thief-catcher, and though I eluded his vigilance for some time, he caught me at last. In prison the parson told me how I ought to have been brought up. He found that I had never been idle, that I had laboured in my calling, that I had never robbed my father or cheated my landlady, and that to the best of my ability I had done what I was told to do, and yet I was put in gaol; and if I had not been a very little boy, the parson said, I should have been hanged. There are some hundred boys in London who are all living as I lived; and when I was tried, a gentleman in a great wig talked very kindly to me, and if I knew what his name was, I would send this letter to him. He said he would have a school in Dyott Street, where boys might be told what was right; and I think, sir, before they are caught and hanged, it would just be honest to tell them they are in danger of it, and to tell them what is law and what is society, and not to let them hear of it, for the first time, when they are tried. I am going, they say, among savages, and I never desire to come back. The savages would have taken care of my education; have taught me to hunt, shoot, and fish, and would have told me how to be a great and good man; but the Christians have not done so, and if it was not that I am sorry for my companions that are left behind, and hope the gentleman in the large wig may see this letter, I would not give myself the trouble of asking my fellow-prisoner to write it.

"Jack Wild."

There can be no question that the amount of juvenile

* Alice, or the Mysteries.

† Physiognomie, Edit. de la Haye, tom. ii., p. 169.

delinquency is on the increase—nay, there are seminaries in which the art of pocket-picking is carried on most ingeniously, so that the description in Oliver Twist, of the game between the jew, Fagan, and his "artful dodgers," is not all fiction.

Mr. Richard Gregory, in his evidence before the police committee, says,—"I went the other day to a house in Wentworth Street, Whitechapel, which is kept by a very notorious character, and there were eighteen or twenty men and women, boys and girls, in bed together, in two rooms. The fellow who keeps the house had a sort of table for them. Some pay sixpence for their bed, some fourpence, and they all go out thieving. If they steal a handkerchief; the man says, 'You had your dinner yesterday, that was *fourpence*, I will take this handkerchief for it;' and if they steal a watch which is worth £20 or £25, it will fetch 20s. in the market; then he says, 'This will go on for next week.'" There is, perhaps, with the single exception of Destructiveness, no organ that is more stimulated and cultivated than Acquisitiveness; we need not therefore wonder that it is grievously abused. Whether we look at the merchant, the manufacturer, or the shopkeeper, the cry is, "Every one has a right to do the best he can for himself." In order that Acquisitiveness in excess may be more distinctly seen, and with the view, if possible, of moderating its present excessive action, we will note a few of its workings. Let us look at the tradesman. "The tendency of tradesmen to speak by the card, is made manifest by the enormous extent to which goods in the present day are ticketed. At one establishment, articles are being '*given away*;' whilst, at the next door, the proprietors are undergoing the daily torment of an '*alarming sacrifice*.' One would imagine self-immolation was a popular pastime with the tradesmen of London. Nearly every window announces the determination of the proprietor '*to sell considerably under prime cost*;' from which it would seem that keeping a shop was a piece of disinterestedness, by which one man determines to victimise himself, and occasionally a few creditors, for the benefit of the public in general. These sacrifices, however, do not seem to be wholly without their reward, for the tradesmen who resort to them very frequently prosper, in spite of their recklessness of their own interests. Thus, while the tickets in the window bespeak '*a ruinous sacrifice*,' the premises themselves display a '*splendid enlargement*,' and when sacrifices are to be performed, the temples are often decorated in a style of gorgeous magnificence. That sacrifices are made, there can be no doubt, but it is another question who are the victims."*

To buy in the cheapest market, and sell in the dearest, is a rule, the justice of which is seldom called in question. It is, however, if fairly analyzed, the rule of Acquisitiveness, and in absolute antagonism to the sentiment of justice. That rule is, "Whatsoever things ye would that men should do to you, do ye even so to them." With this rule before us, we say that every man has not a right to do the best he can for himself, if that right interferes with the right of his neighbour. How far the law of justice is observed by the keepers and customers of cheap shops, is a question worth considering. Such a rule has little sympathy with the spirit which grinds the faces of the poor, and strives to prosper by underselling the fair trader.

Mutual benefit is the soul of business. The announcement of "*ruinous prices*," if true, are an injury to legitimate trade; if false, they are a fraud upon the public; and fraud, in whatever way it is exercised, is an abuse of the organ of Acquisitiveness—a violation of the principle of justice. In either case, the customer's saving, whether real or supposed, cannot be honestly obtained; and those who prefer feeding the flames of voluntary martyrs, to providing fuel for honest men to cook their dinners with, are little or no better than receivers of stolen goods. On the other hand, they who mulct their customers by short weight or short measure, are as certainly thieves as those who put their hand into their neighbour's pocket, and rob him of his cash. Look again at the system of trade in too many shops, we had almost said all. The shopkeeper stands behind his counter like a spider in his web, and every customer he looks upon as his legitimate prey. In the exposure of his goods, lying and false affirmation are his legitimate weapons. If his customer is simply honest, and believes his affirmations, and listens to the praises bestowed upon his goods, and pays the prices asked, 'Ha! ha! ha! what a green horn! How far will a fortune go with him?" Want of Conscientiousness, Secretiveness, and Acquisitiveness, are the ruling powers of such a shopkeeper, yet how indignant would he be, if he were told what he really is, A THIEF!

Or turn to the merchant. How foul have been his dealings *on change*! The words of good old Jeremy Taylor are as true now, as when first conveyed through the medium of a sermon in condemnation of covetousness and thievery. "In this world, men thrive by villany! lying and deceiving are counted just, and to be rich is to be wise; and though little thefts and petty mischiefs are interrupted by the laws, yet if a mischief becomes public and great, and robberies be perpetrated by fleets and armies, it is virtue, and it is glory!" We say, such merchants, such warriors, are thieves, as much under the influence of Acquisitiveness in excess, as the miserable wretch who steps on the tread-wheel; though it may be in the words of poor *Jack Wild*, they have eluded the vigilance of the thief-catcher. The system of spoliation by the great landholders, called protection, was little else than a system of Acquisitiveness in excess. Sympathy for the poor, they had none—unless, indeed, by words. The condition of the agricultural labourer, until very recently—and it is not even yet very enviable—was one of misery and want. The "*Times*" thus graphically describes the state of the poor in agricultural districts:—"We give the poor man every right and privilege under the sun—*upon paper*. He is the highest and loftiest of human beings—*in Blackstone's Commentaries, and De Lolme on the Constitution*. He is free, independent, and master of himself, and a lord of the creation; in company with the squire, lawyer, and surgeon of the parish, as good as any of them. His house is his castle, and the air of heaven his birthright. He lifts up his hand and says, '*I'm a man and all that*.' The only drawback from this high state of existence is, that he has often no bread to eat, and that both the bodies and the souls of these favoured beings are allowed to take their chance, as the saying is."

But if further examples are needed of the effects of Acquisitiveness, look in the daily papers. How many poor wretches are there, whose only escape from suffering seems to be the Thames, or the nearest river!

Money seems to be the chief thing, at least in the estimation of many, for which we are called into existence. Boys are taught its value from the moment they enter the counting-room, nay, almost from the moment they begin to think at all.

A merchant, it has been said, has no faith but in his banker. The Exchange is his church, the desk is his altar, the ledger is his bible, and his money is his God. With all these illustrations before us, have we said too much in affirming that Acquisitiveness is the most industriously cultivated organ in the whole brain—the organ which it is thought impossible to stimulate too highly? While we set the example in the higher departments of society, of clutching at everything we can get, and doing the best we can for ourselves, is it to be wondered at that there are thousands, who, like *Jack Wild*, think they are doing no more than an industrious man should do to acquire money by any means which offers? Assuredly not! There remains then nothing but education, and a cultivation of the Christian precept, "Thou shalt love thy neighbour as thyself," to remedy this state of things, and to bring this organ down to the proper level it should occupy, namely, that of economy in providing for the period when strength fails, and when more comforts and conveniences are needed than in the heyday of youth and high health.

The proper exercise of Acquisitiveness under the influence of conscience and the moral powers, renders it one of the most useful of the animal propensities. It is then the spirit of economy, frugality, and forethought. It avoids all waste and squandering. It "gathers up the fragments that nothing is lost."

* Punch.

9. CONSTRUCTIVENESS.—The seat of the organ of Constructiveness is anterior to that of Acquisitiveness, and lies under the place where the frontal, parietal, and sphenoidal bones unite. Its appearance and situation vary according to the development of the neighbouring organs, according to the basis of the head, and the size of the zygomatic process. If the convolutions in the situation indicated project more than the external angle of the orbit, then the organ of Constructiveness may be admitted as large. If the basis of the skull be narrow, it lies a little higher than in heads which are very broad in the basilar region, and across the zygomatic processes. Moreover, it is covered with one of the masticatory muscles; this must, therefore, be examined by the touch, before the exact size of the organ in question can be distinguished.

Dr. Gall thus describes its discovery.* "At Vienna, Dr. Scheele, of Copenhagen, had attended one of my courses of lectures; thence he went to Rome. One day he suddenly entered my house when I was surrounded by my pupils, and showed me a skull in plaster, on which he begged me to give him my opinion. I immediately exclaimed that I had never seen the organ of Constructiveness developed to the degree that it was in this cranium. Scheele continued to question me. I requested those present to observe a considerable development of the organ of physical love and that of imitation. How, continued he, do you find the organ of colour? I had not paid attention to it, for it was only moderately developed. M. Scheele then declared that it was the cast of the skull of Raphael which he had just sent me, and that during his residence in Italy, he had found my ideas confirmed by the study of the uniques.

"Many of my hearers spoke to me of a man endowed with an extraordinary genius for mechanics. I described to them, beforehand, the form which his head ought to have, and we went to find him. He was the skilful inventor of mathematical instruments at Vienna. His temples were swollen into two misshapen cushions. Before this, I had found nearly the same form in the head of the celebrated mechanician and astronomer, Daird, an Augustine friar.

"At Paris, the Prince of Schwartzenberg, then minister of Austria, wished to put M. Spurzheim and myself to the test. At the moment when we rose from table, he led me into a neighbouring apartment, and introduced to me a young man without saying a single word. I went to rejoin the company with the prince, and begged M. Spurzheim to examine the young man during his absence. I told the company what I thought of him. Spurzheim had hardly seen the individual, when he came to join us in the parlour, and likewise declared that he thought him a great mechanician, or a great artist in some similar department. In fact, the prince had induced him to come to Paris on account of his great talent for mechanics, and furnished him the means to prosecute his studies there.

"At Vienna, and in the whole course of our travels, we found, among all the mechanicians, architects, draughtsmen, and sculptors, this organ developed in proportion to their talent."

When Dr. Spurzheim was in Edinburgh in 1817, he visited the workshop of Mr. James Mylne, brassfounder, and examined the heads of the workmen and apprentices.

"On the first boy presented to Dr. Spurzheim, on his entering the shop, he observed he would excel in anything he was put to. In this he was perfectly correct, as he was one of the cleverest boys I ever had. On proceeding further, Dr. Spurzheim observed of another boy that he would make a good workman. In this instance, also, the observation was well founded. An elder brother was working near him, whom he also said would turn out a good workman, but not equal to the other. I mentioned, said Mr. Mylne, that in point of fact the former was the best but both were good. In the course of further observations, Dr. Spurzheim remarked of others that they ought to be ordinary tradesmen, and they were so. At last he pointed out one, who, he said, ought to be of a different cast, and of whom I should never be able to make anything as a workman, and this turned out to be too correct. For though he had served seven year's apprenticeship, he was not able to do one-third of the work of other individuals. So much was I struck, observed Mr. Mylne, with Dr. Spurzheim's observations, and so correct have I found the indication presented by the organization to be, that when workmen, or boys to serve as apprentices, apply to me, I at once give the preference to those possessing a large Constructiveness; and if the deficiency be very great, I should be disposed to decline receiving them, convinced of their inability to succeed."

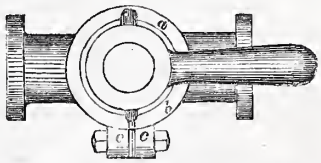
The constructive faculty in the bee is singularly happy—in the formation of their cells, they are the most complete geometricians. Scarcely could a hexagon be more perfectly drawn by a skilful mathematician, than is presented in the cells of these insects. But this is not all; it was said by Pappus, an ancient geometrician, that of all other figures, hexagons were the most convenient, for, when placed touching each other, the most convenient room would be given, and the smallest lost: so the instinct of the bee has determined. The cells of the bees are perfect hexagons. These in every honeycomb are double, opening on either side, and closed at the bottom. The bottoms are composed of little triangular panes, which, when united together, terminate in a point, and lie exactly upon the extremities of other panes of the same shape in other cells. These lodgings have spaces like streets between them, sufficiently large to let the bees go in and out, but yet narrow enough to preserve the heat of the united hexagons. What the bee is among insects, the beaver appears to be among quadrupeds; and the faculty of Constructiveness seems in them to approach as near to the same faculty in man, as is seen in human erections.

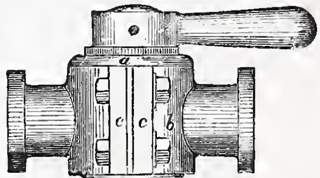
We shall notice some important particulars connected with this organ, when we come to treat of the organs of Form, Size, and Weight, in combination. The organ of Constructiveness is fully established.

* Gall's Works, vol. v., p. 108.

BODMER'S IMPROVED STOPCOCK.

FEW, if any, of the minor parts of steam machinery give so much trouble to keep in repair, as the common conical keyed stop cock. One very obvious reason is, that from the conical shape of the key, the larger diameter passes through a much greater space in a given time than the smaller one; the wear at that part is therefore proportionally greater, and leakage is the necessary consequence.





The subjoined figures represent an improved cock, which was introduced into steam machinery some time ago, by Mr. Bodmer of Manchester, and in which this objection is entirely done away with, by substituting a cylindrical key for the conical one. *a* is a slight flange cast to the upper end of the key, for the purpose of keeping it in its proper place, as from the absence of the cone, it would be liable to slip through the shell *b*. The office of the cone is supplied by casting on the shell two projecting lugs, *c c*, or this projection may be cast solid, and afterwards sawn through; bolts are passed through these lugs for the purpose of contracting the shell as the surfaces wear. The particular purpose for which these cocks were introduced, was for locomotive engines, in which, on account of the high steam pressure used, the disadvantages of the common cock are perhaps more felt than in any other situation where they are applied.

HISTORY.

CHAPTER XIX.

THE GERMANIC KINGDOMS.

The territories of the new Emperor Charlemagne, included all that could in his time be regarded as belonging to the European system, with the exception of Britain. Two provinces of the Western Empire—Africa and Spain—had become the property of the Arabic disciples of the Koran. These invaders from the South had even contested for a while the lands between the Garonne and the Pyrenees, with their Northern rivals; and they contested a precarious and shifting domination over Sicily and the southern extremity of Italy, with the Court of Byzantium. The countries east of the Elbe and north of the Baltic, had not yet emerged into history. For the period therefore of 400 years, to which our attention is at present directed, the history of Europo is mainly the history of those states which after experiencing many changes of dynasty between the year 400 and the year 804, came ultimately to be united under the sceptre of Charlemagne. The history of European civilisation is now at last confined to its own soil, although it does not yet relate to the whole of Europe.

In last chapter, we traced the establishment of various dynasties which arose out of the ci-devant Roman provinces. We are now to attempt an estimate of the effect of this great revolution upon the morals, intelligence, and refinement of society; in doing so, we shall treat, first, of the organization of civil society; secondly, of the organization of the church; thirdly, of the moral and intellectual character of the people living within the pale of these two great institutions.

I. When the Goths, Burgundians, Franks and Lombards founded kingdoms in the countries formerly subject to the Roman empire, they did not extirpate the conquered race, neither did they transform the Romans into Germans by forcing on them their manners, constitutions, and laws. In every province where the Germanic tribes gained the ascendancy we find one uniform system pursued. In the territories secured by the Burgundians immediately after the conquest, the land was partitioned between the Romans and Burgundians. Of the house, offices and gardens, the Burgundians received the half; of the arable land two-thirds; and of the bondmen one-third. Woods remained common property. The free Burgundians, who came later, received, without any of the bondmen, half of the cultivated land; and the manumitted Burgundians got merely the third. The authorities from which we derive our knowledge of these facts, prove clearly that there was an actual division of the rights of property. All estates were not at once broken down into these divisions; an estate was assigned to each Burgundian, and with him the Roman was obliged to divide it in the manner I have mentioned. One author indeed asserts that the Burgundians only partitioned the domains of the nobility or great landed proprietors of Gaul. The Roman estates were, we have every reason to believe, of considerable size; and the excess of their number above that of the free Burgundians, would show the quantity of land still remaining undivided. As fresh recruits came up to the support of the Burgundians in their new settlements, fresh lands would be allotted for division. The Roman is sometimes styled the Hospes of the Burgundian quartered upon him; and at other times the view of their mutual relation is reversed. This is the most delicate epithet for what an American would term a *squatter*, or one of our own ancestors a *sorner*, that the wit of man has devised. The share which the Burgundian *acquired* (!) by this division, is called *sons;* and the right to it, *Hospitalitas* (!) Two other rules were observed. Every Burgundian, by receiving land from the king, was excluded from depriving his Roman hospes of the *sons*. And while upon the sale of every *sons*, the Roman *hospes* was entitled to the first offer, no Burgundian could sell his *sons*, unless he were the proprietor of other lands. The West Goths, like the Burgundians, deprived the Romans of two-thirds of their land; and took not merely a tribute of a part of the produce, but enforced a true partition of the land itself. Both the Gothic and Roman allotment was called *sons*. In the Frank empire, so far as historical accounts reach, there never was a uniform mode of dividing the land; and we are thus left without any direct information on that subject. Almost the whole of the Frank conquests within what had been Roman territory, were from preceding Germanic conquerors, and a species of confiscation of the property of the dominant race might with them supersede the original division. Certain it is, however, that the Franks acquired lands as well as their predecessors in the career of conquest, and equally certain that we find Romans living and holding property among them.

The holders of this re-distributed property, lived together in a manner which is at first difficult to conceive by those habituated to our social arrangements. Modern Europeans are apt to assume that the law to which an individual owes obedience is that of the country where he lives, and that the property and contracts of every resident are regulated by the law of his domicile. In this way the distinction between native and foreigner is overlooked, and national dissent is entirely disregarded. Not so, however, in the middle ages; where, in the same city, the Lombard lived under the Lombardic, and the Roman under the Roman law. The races lived together, and preserved their separate manners and laws. From this state of society arose that condition of civil rights denominated personal rights, or personal laws, in opposition to territorial laws. At first two laws only were admitted: the law of the conquering race and the law of the conquered Romans—in Spain the Visigothic and Roman laws—in the Burgundian state the laws of the Burgundians and the Romans. But when a Germanic kingdom subdued and incorporated other Germanic states into it, the laws of the conquered German races were acknowledged in the same way as the Roman had been formerly. Thus, in the northern parts of France, the Frank and Roman laws would at first be exclusively received; but under the Charlemagnic dynasty it would become necessary to admit likewise the laws of the West Goths, Burgundians, Alemans, Bavarians, and Saxons, because these as nations belonged to the empire. The rule by which it was determined by which law an individual should regulate his dealing and assert his rights was that of descent; but from this there were exceptions. The clergy, whatever their parentage, were bound to live according to the law of the church, which was framed upon the Roman law. A woman was bound by the hereditary law of her husband, so long as he lived; after his death she reverted to her own hereditary law. A natural child was left free to choose its own law. This state of society is strikingly pourtrayed in a letter from the Bishop Agebard to Louis the Debonnaire:—"It often happens that five men, each under a different law, may be found sitting or walking together; and if one of them is involved in a law-plea, he cannot produce one of his companions as a witness, for all witnesses must be of the same law as the party accused."

The predominant form of the judicial tribunal varied in different parts of the immense territory which was ultimately united under the sceptre of Charlemagne, according as the Roman or Germanic ingredients of society predominated. Within the territories of the Roman empire, the civic or municipal constitution was all-pervading. Within Italy, the municipal magistrates had the jurisdiction, in the first instance, to an unrestricted amount, only a limited right of appeal to the governor of the province, and from him to the central authority in Rome being competent. In the previous act of Italy it was only a few of the largest and most important cities that possessed jurisdiction: all judicial matters being elsewhere disposed of by the *Rector* or *Vicar* of the province in his circuits, or by his *legati* or *vicus*. The effect of the institution of the new Germanic states was to subvert entirely the great public institutions of the realm, but with the exception of the transfer of property and the substitution of personal for territorial laws, to leave all local institutions much as they were. Under these circumstances it was natural that in Italy, and in those large and powerful cities out of Italy possessed of Italian municipal constitutions, the judicial arrangements should remain in *statu quo;* while in all districts in which public officers of the general state had discharged the judicial functions, German functionaries should supersede the Roman. In a certain class of contentious judicial business, and in all voluntary judicial business, we find the tribunal composed of the assembled freemen of a community or settlement, recognised and active in all the Germanic states. But we have already had occasion to notice that even in their own land a class of men was growing up among the Germans, and gradually subverting their old democratic institution. I allude to the *Fursten*, or *Konongr*, with their *Dienstgefelge*—the warrior-chiefs with their trains or followers. It was this class which had been the strength of the Roman armies while the Roman empire yet remained. It was this class that had obtained the ascendancy in every confederacy of Germanic tribes which set forth to conquer new abodes, and had converted it into a rude monarchy or warlike oligarchy. And according as the organization of this army in search of new settlements was more or less complete, we find a class of judges holding their authority from the leader more or less permanently established. It is a fact easily accounted for, that none of their migratory confederacies obtained exclusive or permanent conquests until they were completely organized, and power was concentrated under one leader; and the habit

of submitting the chief management to him would be strengtheneo in a new country where constant watchfulness was necessary to repel the assaults of external and internal foes. Under these circumstances we find an officer introduced into every district of the new states, combining the judicial and civil powers of the Rector with the military functions of the *Comes* of the Roman empire. The title of this functionary in German was *Graf*—apparently connected in signification with *Gari*—the old German designation of the district appertaining to a community. This is the origin of our Sheriff, or *scire-graf.* It is still the German title corresponding with Count or Earl. The Latin counterpart—Comes—is the original of Conte, Conde, and other corresponding titles.

These, then, are the outlines of the constitution of all the Germanic states erected in the Provinces of Rome, including among them the empire of the Franks, which ultimately absorbed them all. At the head of the state was a king, succeeding by hereditary right in a certain family, without, however, any observance of exact lines of descent, primogeniture, and nearness of relation. In each province of the kingdom was a Graf, appointed by the king, and responsible to him. The Graf had the management of military affairs in all the provinces. In those where the municipal constitution did not obtain, he exercised also his judicial authority, except within those cities which had been Roman municipalities. In the Roman municipalities, from the beginning, the old jurisdiction and civil government of the Romans continued under Charlemagne. An institution analogous to that of the Deurians, called Scabini Schoffen, were introduced even in the Germanic communities. In all the Germanic states, where the Roman institution of municipal government survived, the Roman mode of taxation was retained, the Deurians being responsible to the Graf for the full amount of the assessment within their municipality, and the Graf to the king, for the full amount of the assessment within his county. In the other Germanic kingdoms the royal revenue consisted of the produce of the crown-lands, and annual presents from the principal men of the following—a class among which we have the first rude germs of what subsequently developed itself into the feudal system.

II.—It is now time to turn our eyes towards the progress of the Church, which, during these events, had been growing up into a great, and, in a great measure, independent power.

Subsequently to the Council of Nice, the chief management of church affairs was concentrated in the hands of five patriarchs, or metropolitans: the bishops of Constantinople, Rome, Antioch, Alexandria, and Jerusalem. The Bishops of Rome and Alexandria declined the Jewish title of Patriarch, and resumed that of Pope, Papa, or Father—a designation which, even subsequent to the overthrow of the western empire, was common to many of the western dignitaries of the church, and which is still the prevailing designation of all the clergy of the Greek church.

In each of the provinces in which Germanic kingdoms were erected, the church was already possessed of considerable landed property; the members of the church were organized in a system of subordination, enforced both by temporal influence and the sanction of religion; the superior clergy were the most learned men of the time. All the Germanic troops garrisoned within the empire were at least professing Christians, and with the exception of the Franks, the most important of the invading tribes had also been baptised. The new comers were prepared not only to leave the church unmolested, but to add to its authority. Even the temporary heathenism of the Franks tended ultimately to increase the power and dignity of the Patriarch; and still more, to promote the unity of the organization, and its subordination to the metropolitan see of Rome. The Goths and Lombards were of the Arian faith; the churches within the Roman empire had adhered to the orthodox doctrines. The churches in Gaul were not conciliated by the liberation of their conquerors; they gladly hailed in the new and somewhat suspicious convert, Clovis, an instrument for the subversion of the heretic empire of the Goths, and their influence materially promoted his conquests. He and his successors felt what an important ally they had secured, and the Frankish monarchs, down to the time of Charlemagne, were, with few exceptions, the patrons and the patronized of the orthodox churches within their dominions. This drew upon him the eyes of the bishop of Rome, hard pressed on many occasions by the heretic Lombards, and indignantly defended by the Byzantine emperors. The Patriarchate of Rome was offered to Carl Martell, and accepted by his son Pipin. The greater honour of Emperor was reserved for Charlemagne. The last mentioned monarch naturally sought to reward the services ef the Pope by compliances in turn. Charlemagne found an additional reason for befriending the Roman court. Rome, so long the seat of empire, was also the seat of learning, accurate business habits, and polished manners. Charlemagne was delighted with the more apt organization of the Roman church, with the superior learning of its clergy, and with the greater beauty and decorum of its ritual. He struggled hard to assimilate the Frankish churches to it in all these respects; and in his anxiety to obtain this end he found an additional inducement to enforce the authority claimed over them by the æcumenical bishop of Rome, to those which considerations of friendship and gratitude had already created.

By this means a greater uniformity and coherence among the churches in the whole of western Europe, not in the hands of the Arabs, was introduced. The Bishop of Rome was secured in the exercise of that authority over them which he had so long asserted. His own temporal power and influence were considerably increased. As yet he had obtained no temporal jurisdiction or authority in Rome beyond that which was, from custom, voluntarily conceded by Christian communities to their bishop. But the gift of the Exarchate of Ravenna, by Pipin, confirmed by Charlemagne, had laid the foundation of his claim to be considered as a temporal sovereign; though he was most wary in insinuating his claims. Meanwhile the churches throughout the empire of Charlemagne were rapidly advancing in temporal wealth and influence. That monarch adopted a policy naturally suggested by events in the declining empire of Rome. He conferred such powers upon the bishop in each province as made him an efficient counterpoise to the Graf or Count. Thus was the tendency previously evinced by the Church to assume a similar character, confirmed. The church had long attempted to establish a claim to the titles of the faithful on the strength of the Old Testament dispensation. Charlemagne went a step beyond this, and bestowed upon it, as far as his power extended, the titles of all subjects of the Frankish empire, as well of infidels as of the faithful. In each bishopric large funds in land, and the tithe of all the lay property, were allotted to it. The clergy were obliged to live in the house with the bishop, according to the canonical rules; and, where the bishopric was large, affiliated, collegiate, or prebendal churches, were instituted at convenient distances. The dignitaries of these churches were endowed with extensive jurisdiction in secular affairs; and their superiority in learning to the laity, occasioned them to engross at court—whither, as holders of large landed estates, they as well as mere secular dignitaries, were summoned on state business—all those offices to the discharge of which literary acquirements were indispensable. The collegiate and canonical mode of life promoted the final establishment of the celibacy of the clergy; and all those powerful and organized bodies, emancipated from the ties of domestic life, were subordinated to the bishop of Rome—himself on the eve of becoming, if not already become, a territorial sovereign.

III. It is evident that there must have been a wide diversity of social character within so wide a range of territory. In Rome, and perhaps in Italy and the south of Gaul, there was among the free Roman citizens, with all their feebleness of character, considerable refinement of habits, and an inclination towards literary pursuits. Among the provincial Romans there was greater rusticity—a greater admixture of Celtic and Germanic manners and customs with those of Rome; and east of the Rhine, and north of the Danube, the population was very nearly in the state described by Tacitus. In 724, Boniface commenced his mission among the Hessians by burning down with his own hands the sacred oak under which they were wont to sacrifice, while the terrified inhabitants looked in vain for the supernatural fire that was to avenge the sacrilegious deed. The people were still hunters and tillers of the soil; and the civil organization of the Saxons under Charlemagne seem little if anything in advance of that of the Zuevi in the time of Cæsar. Now the effect of the revolution which established several Germanic kingdoms, and finally one Frankish empire on the ruins of the Roman empire, was to throw all these various grades of refinement rudely through each other. Rude Germanic warriors came to reign at Rome amid a higher refined population, and Romish priests and captives carried the habits and feelings of Rome far into the innermost recesses of the Heregnian forest. The Romans lost in refinement and knowledge, but they contracted somewhat of the hardihood of the Teutones. On the other hand, the indigenous Germans lost somewhat of their old simplicity and rude sincerity, but they gained ideas which, fermenting in their minds, left them no rest until they had marked out a higher civilization. Progress—advance in civilization—we can scarcely call what took place between the beginning of the fifth and the close of the eighth century, but just as little is it retrogression. We must not allow ourselves to be deceived by the absence of great authors and artists; an age may be energetic and intelligent, yet leave no original work that posterity may care to keep alive.

Of science and literature there was little or nothing. The Germanic tribes never had a written literature, and the subjects of the

Roman empire were fast losing what they had possessed. Not that we must allow ourselves to suppose that the bulk of the population—and above all in the provinces—ever had any to lose. The science of war kept its ground. There were many of the Germanic leaders who displayed natural talents for conducting war on a great scale. At the time of the first incursion of Alaric, the Germanic tribes knew not how to assault cities: this, however, they learned in time; and they mastered tolerably well the system of Roman tactics. In civil combination they did not prove such apt scholars; although they learned that easiest of all departments of government, the imposing and uplifting of taxes. The private account-books of Charlemagne, of which some specimens have been published, would for completeness and accuracy be far from despicable in our own day. The advantage of written testimony to contracts and other legal transactions was so apparent, that the Germans soon adopted it; and thus came the whole Roman system of judicial archives, notaries, &c., to be preserved from destruction. The church continued to erect as costly structures as the means and taste of the brethren enabled them to rear. They had models before them. The mechanic arts necessary for these purposes were preserved: even in England—then the outskirts of civilization—we find the art of making glass known in the seventh century. Chledwig began to have money coined with his own impression in the sixth century. Other Germanic sovereigns had coined money before him; but for the convenience of their subjects, as the Romans took unwillingly any but Roman coins, they had used the impress of the Roman emperors. Priests plied the goldsmith trade in order to furnish their churches with chalices and lustres. The sovereigns were not slow to use the mechanic skill, shown in rearing churches, and furnishing them with plate for the purposes of their own private luxury. Mines were worked even in Germany. A weapon-forger was everywhere to be met with towards the close of this period. A busy traffic was carried on between the Frankish subjects and the rude tribes on their eastern frontier. All along the line of the Elbe from the sea, the Bohemian frontier, Charlemagne instituted staples for promoting his commerce. The Venetians—the refugees from Alaric, Attila, and other plunderers—had already engrossed the commerce of the Adriatic; and an embassy from the city had excited the wrath of the courtiers of Charlemagne, they were so much more splendidly dressed than the whole assembled court. Practical government, the most necessary of mechanical arts, and commercial enterprise, were as active in these days as in any others.

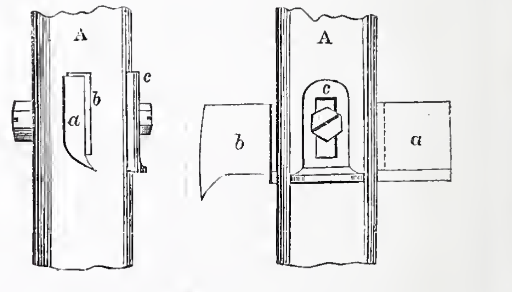
Nor was the reflecting part of our nature left altogether uncultivated. There were schools of law scattered through the various provinces of the Roman empire, and one of these at least we find surviving in the sixth century in Gaul. The law-school of Ravenna, and the schools of general literature in Rome seem never to have been intermitted down to a period long subsequent to the close of that of which I am speaking. It was a rule in the foundation of all churches and cloisters, that the canons and monks should also open schools, and in many instances we know that this was done. The course of education—superficial it may be, but still better than none—consisted, as under the empire, in instruction in the seven liberal arts;—Grammar, Rhetoric, and Dialectics—(called the Trivium, triplex via ad sapientiam); Arithmetic, Geometry, Music, and Astronomy. The church service furnished a constant practical stimulus to the study of music; the necessity of the priests knowing how to determine the annual recurrence of the fasts, was an inducement to obtain a smattering of astronomy. The latter study, as also architecture, can keep alive the desire to study arithmetic and geometry. Thus, even in the actual business of society, there was a substratum whereon the slender science of the age might rest—a something to teach men the practical use of knowledge.

Literature was necessarily cramped by the rude and unformed state of the languages spoken in society. About the commencement of this period, C. Aphilas had reduced the Maeso-Gothic dialect of the Germanic language to writing, in the translation of the scriptures. Towards its close Ottfreed first essayed to reduce the Frankish dialect to grammatical forms. Some progress was made in the development of the Anglo-Saxon tongue. Charlemagne commenced a selection of Frankish poems. The Romanic languages—that is, the engrafting of Latin on a Teutonic base, or of Teutonic on a Latin base—had not yet assumed form and consistency. The literary language was Latin—for with the intercourse with the Byzantine empire the knowledge of Greek had died out. But the old classical authors of Rome—the heathen authors as they were called—had begun to be discountenanced. St. Augustine, (436), was the favourite book of the learned; and well does he merit this compliment above all the writers of his age. Next to him came Bœthius and Cassiodorus, both of whom flourished under Theodoric, king of the East Goths. Still, pitiful though this rehearsal be, we have in the Bishop Agaband a specimen of how far a naturally energetic mind can sway itself up even under such unfavourable circumstances. We have already quoted his description of the working of the personal laws, upon which rested a project for promulgating one uniform system for the kingdom. In 779 he published his "*liber contra damnabilem opinionem putantium divini judicii veritatem igne vel aquis, vel conflictu armorum patifieri.*" The clear eye which could see the folly and blasphemy of these appeals was not blinded to the more homely follies of his time. He complains bitterly of the silly superstition of his countrymen: "in our valleys," he says, "almost everybody believes, distinguished and mean, peasant and citizen, old and young, that there are people who can conjure up thunder and lightning. So soon as it begins to thunder and lighten they say the air is bewitched."

Nor did Agaband stand alone. His contemporary Otfreid hit upon the true cause of the enduring barbarism of his countrymen, in the dedication of his translation of the Evangelists to the Archbishop of Mayence. "Our language," he says, "is esteemed boorish, because we have neither polished it by writing nor by systematic grammar, and because we do not, like other people, employ it to record the deeds of our fathers. For this purpose we use a foreign —the Latin or Greek language. We are anxious to write well in these, but no man is ashamed of the rudeness of his native tongue —in foreign languages we are afraid of a misplaced letter; in our mother tongue we quietly commit blunders at every word. Strange that sagacious and learned men should direct all their attention to a foreign language, and not even know how to write their own." In our own Alfred, and in Charlemagne, men like Otfreid and Agaband found statesmen worthy of them—and there were many such among their contemporaries. Their age was neither an idle, an useless, nor an imbecile age—new blood was in the process of being forced into the dry veins of society. The civil and spiritual powers were blindly, but with Titanic force, groping about to find their respective spheres; and the plot of the great drama, of which the stately epilogue was then rehearsed, has not yet, after ages of terrific and mysterious struggles, reached its denouement.

EXPANDING AUGER.

This auger is intended for boring large holes only: it may be used for holes from $1\frac{1}{2}$ inch to 8 inches diameter. In using it a



guide hole of the same diameter as that of the spindle A is first bored in the wood, and the large tool is then employed to enlarge this hole to the diameter wanted.

The spindle of the auger is pierced through its thickness to receive the cutters *a* and *b*. These cutters have cutting edges adapted to the particular functions which they are intended to perform in the operation as in the small auger. The edge of *b* projects perpendicularly downward, and in use cuts the circumference of the hole; whereas the edge of *a* projects downward and forward, at right-angles to that of *b*, and is intended to scoop out the area of the hole. The cutters being adjusted to the width of the hole to be cut, are held in their position by a pinching screw; and in order to regulate the working of the tool, a sliding piece *c* is attached. It has a slot in it to receive a stud which is fixed in the spindle A, and which has a pinching nut upon its projecting end; by this, the piece is held in its position upon the spindle, and the position which is given to it, regulates the thickness of the shaving scooped out by the shaving cutter *a*. If thought necessary, the lower extremity of the spindle might have a triangular thread run upon it, to lead the tool when working, and in this case, the sliding piece *c* would not be wanted.

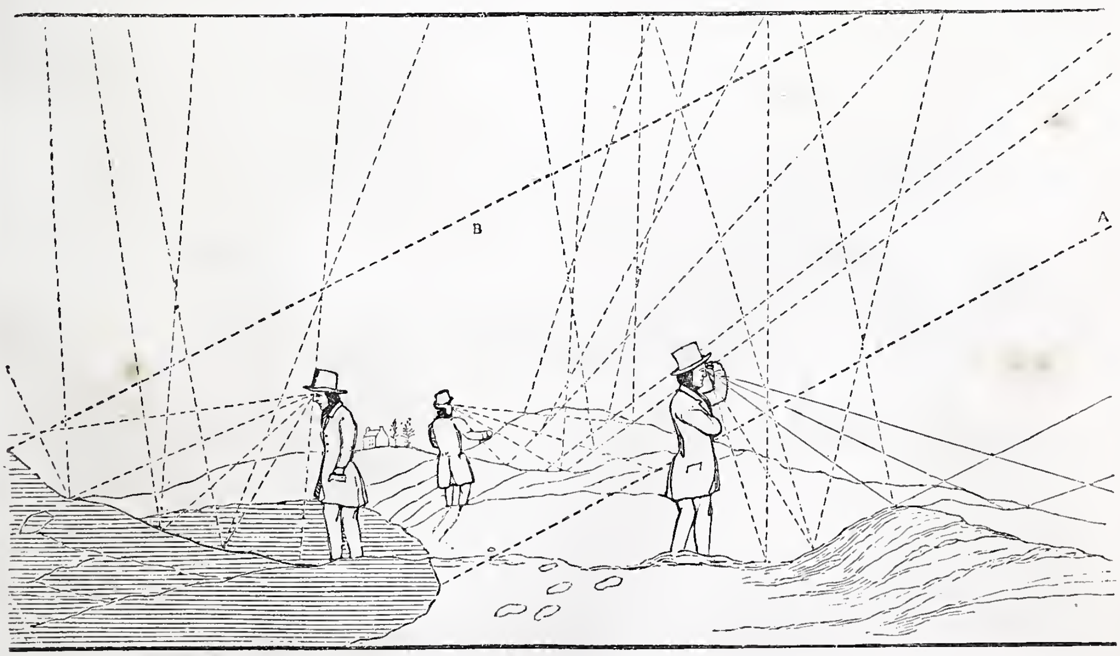
PRINCIPLES OF HARMONIOUS COLOURING, AS EXHIBITED IN NATURE.

BY MR. JOHN HART.

HAVING devoted so much of the former paper (page 596) to Light, Heat, and Sound, I shall now endeavour to show how the principle of illustration there adopted may also be available to the student of art, as it affords a means, by ocular demonstration that will not readily be forgot, of illustrating the effects produced from the reflection of Colour. In painting, to constitute a pleasing picture, besides correct delineation of outline and the proper distribution of Light and Shade, truth and harmony of colouring are absolutely necessary. Practice may make us master of the former, but it requires a familiarity with, as well as a correct knowledge of, the doctrines of light, and an attentive observation of nature, to make us master of the latter. Now, as all light proceeds from the sun, and as all objects possess the power of reflecting more or less of the prismatic rays, or colours inherent in the light, and as all reflected light is modified by, or partakes of, the colour of the object from which it is reflected; and as we also learn from childhood to judge of colours not from their ever-varying hues under different lights, but from what is considered their true or permanent colour, therefore nothing is more deceiving to the uninitiated eye than the apparent colour of objects. We may take snow as an example, it being the nearest approach to a pure or perfect white. In looking upon the face of the country after a heavy fall of snow, the common observer would probably exclaim, How beautiful and white the fields now appear, the whole face of the country is a sheet of perfectly pure white! what can be whiter than the new fallen snow! what can be purer than the new driven snow! &c. To the artist, however, the snow would only appear of a pure white where its glistening surface reflected the sun's light direct to his eye; what was in shadow, or the fields that lay sloping to the north or west, would appear light azure, grey, or brown, according to the colour of the northern or western sky, because the light reflected from its surface would be proceeding from the azure or grey colour of the atmosphere, and therefore if the sky becomes overcast or obscured by clouds, the snow will appear grey, although, when contrasted with the dark brown horizon, it will be considered as pure white, in absence of the brighter light from the sun. But we need not wait for a fall of snow to observe the effects, when we can again have recourse to the paper. Thus if we take a sheet of writing paper and bend it, or if we open a letter in sunlight, we will observe the same effects of colour; that portion of the paper on which the sunbeams fall will appear white, while the parts in shade will appear of a blue, or grey, or brown tint, according to the colour of the light which falls upon them—azure from a clear sky, grey or brown from a cloudy sky, or from the surrounding buildings, and orange or red from the crimson clouds of the setting sun, and so on. But the best form of this experiment is to take a roll of white paper of about two inches diameter, and go into the open fields with it, then hold it up in a line with the eye; if the sky is clear, the upper portion of the cylinder will appear of a deep azure, gradually softening into a grey or yellowish tint as it approaches the part opposite the sun, which will be the line of white, or a very light yellow beneath this; it will again shade into grey, light azure, then into the tints of the horizon, with green or brown according to the colour of the surface upon which we stand. Thus we have only to examine the colour of the object from which the light comes to determine the particular hue that the respective shades ought to have. Let us now apply this to an object, the colour of a white horse for instance, standing in sunshine about 6 o'clock in a summer evening. The upper portions of the body and the bright lights upon the head, the neck, the shoulder, the barrel, and the quarter, will not be pure white, but of a light yellow or orange tint; the croup and hollows in the back and upper portions of the loins will be grey, passing into blue or purple; the sides and belly a yellowish grey, shading into a blue tint, then into the brown or greenish tints of the ground upon which he is standing. Wovermans seems to have made this his particular study, hence the pleasure we derive from looking at his pictures, which are true to nature, although not a spot of puro white will be found upon any of his white horses in an afternoon light.

We will now have recourse to our paper slips as a means of ocular demonstration to the young artist of the true principles of colouring. In the former paper I showed that by folding a strip of paper to any angle we chose, the two portions of the strip would invariably represent the incident and reflected rays, and the fold the reflecting surface; we will now apply this principle to discover the source from which the light is emanating, and by which any particular portion of the surface of an object is illuminated that

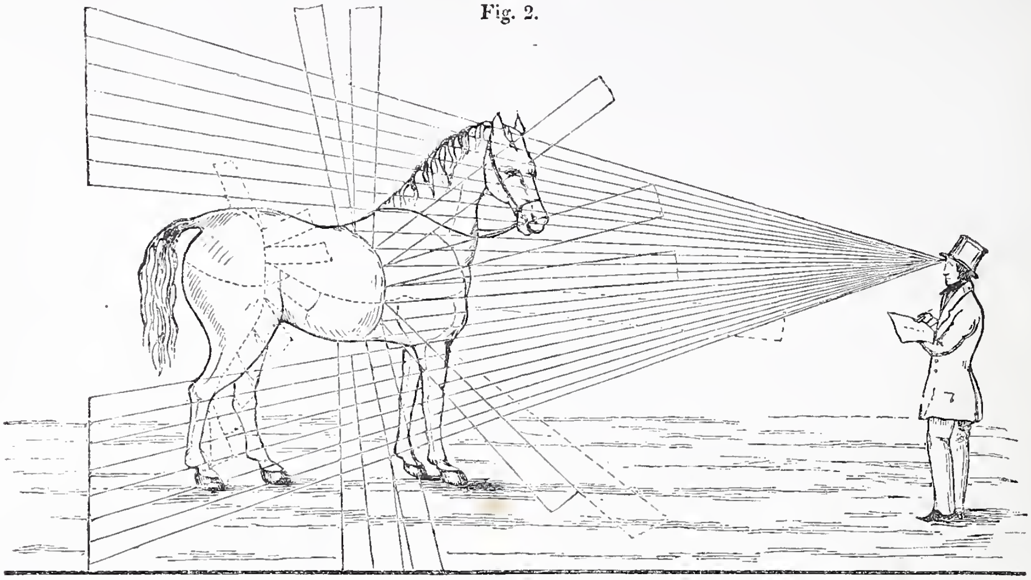
Fig. 1.



we may be looking at. We will take the snow-scene, for example. Let fig. 1 represent a country covered with snow; then, let us take a strip of thin paper, or, what is better, oil-paper, because through it we can easily see the line of surface; having cut it to an angle of 10 or 12 degrees, to represent the rays of light converging to the pupil of the eye, and having thrust a pin through the apex

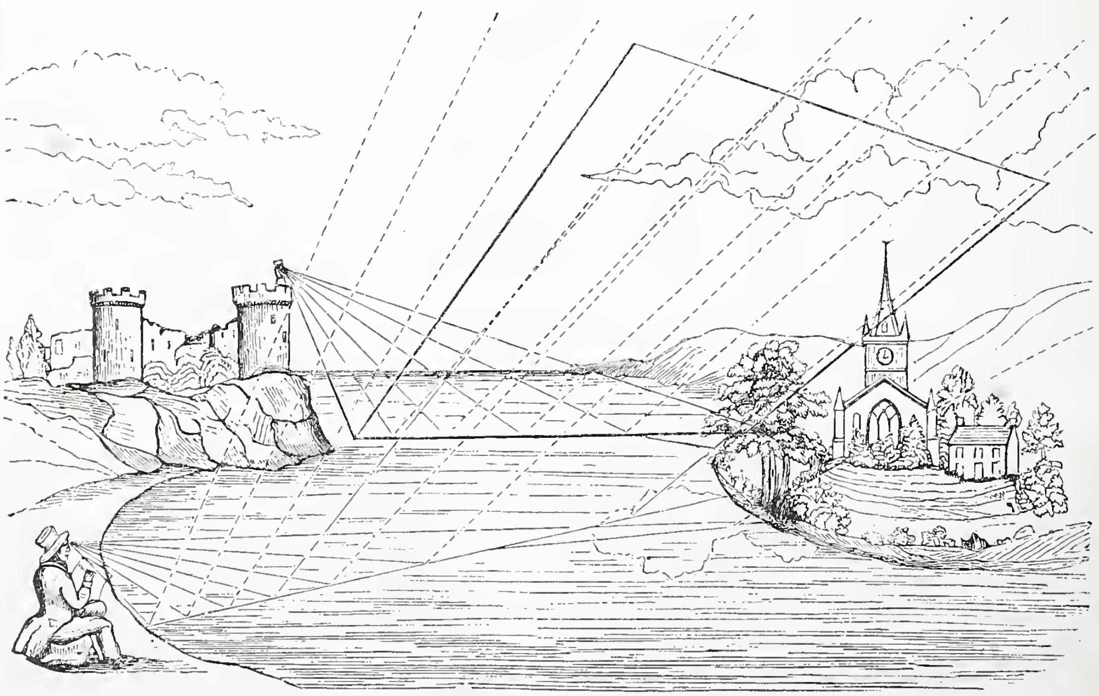
of the paper and the place of the eye, turn the slip round to any particular spot, and fold it upon the line of surface, the remainder of the slip will invariably point to the source of the light which is reflected from that particular spot to the eye. Thus, let the dotted lines A. B. represent the shadow of a cloud, and of course the direction of the sun, then the reflection from the surface of the bank in front of the figure to the right being in the same direction, the sun's light will be reflected direct to his eye; hence this particular spot will be a pure or positive white, being the brightest portion of the whole landscape to his eye; beyond this the slope of the bank will reflect the light of the sky below the sun, shading downwards into the colour of the horizon; while the slope of the bank at his feet, being in shade, as well as the snow in the shadow of the cloud in front of the figure to the left, will to both spectators appear of an azure hue, as it will be perceived that the light reflected from these surfaces to the eyes of both is proceeding from the sky near the zenith. We shall now apply this principle to illustrate the gradations of colour upon a single oojcet—the white horse, for instance. If we take a piece of oil-paper and draw a number of converging lines upon it to represent rays converging to the eye, then lay it upon the figure of

Fig. 2.



a horse, as fig. 2, and with a pencil draw either the curve of the side, the neck, and shoulder, the body, or the hind quarter; with a knife, cut the converging lines up to the curve you wish to try, and fold them upon the curve as represented in the figure,

Fig. 3.

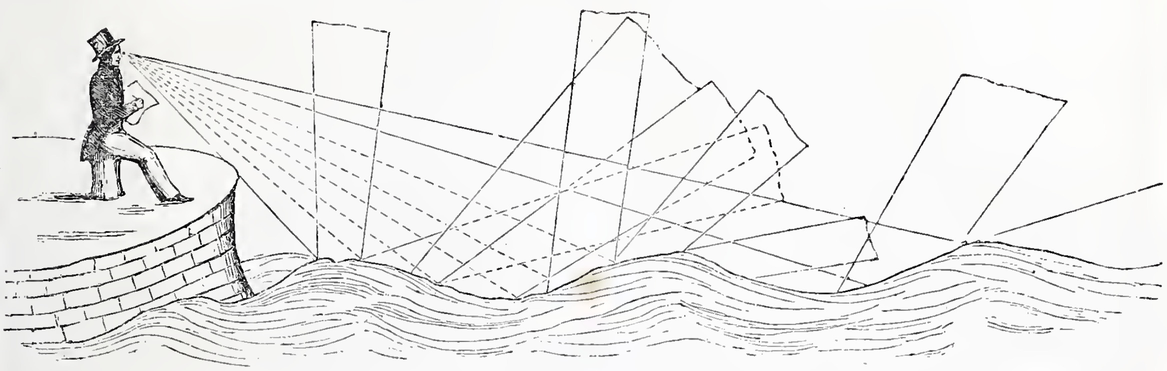


they will at once show where the light is proceeding from, and of consequence the apparent colour of that part of his body. Thus the croup is reflecting the zenith lights, beneath this it is the colour of the sky near the sun, then the direct light from the sun, beneath which is the light of the horizon, and the reflected light from the surface of the ground; the dotted folds upon the hind quarter show

how the tints upon the rest of the body are produced; but to insert any more lines or dotting would only render the figure confused.

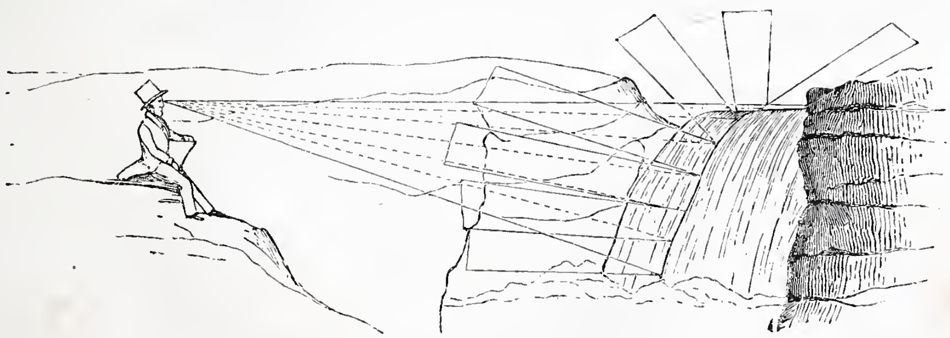
We may also apply this principle to illustrate the nature of reflection from the surface of water. Since we sometimes observe the effects of a good picture lost by the artist not attending to this principle, his sheet of water not appearing as a level surface, or perhaps glaring like a spot in the picture that offends the eye. This error may arise from the artist not clearly comprehending the laws of the reflection of light,* and therefore painting heedlessly from some former sketch which he had taken from a very different point of sight than where he has introduced it in the picture. To show the necessity of attending to this law, let fig. 3 represent two artists sketching the same village: the one near the level of the water, and the other on a height. Draw a line along the surface of the water, direct from the artist to the object he is sketching, at the level of the surface of the water; take an angular piece of oil-paper and fold it up like a fan, to make radiating cresses upon it, or with a pencil draw a number of lines radiating from the apex; push a pin through this centre and into the place of the eye of the artist, as shown in the figure, and place the one edge of the paper to the beginning of the line or surface of the water at his feet; fold the paper over upon it, the lines or cresses will at once show where the reflections from the sky, the clouds, the distant mountains, or the church-spire, trees, &c., will appear to each artist as reflected from the surface of the water. Thus to the one at the water's edge, the top of the spire appears half across the river; while to the other on the tower, it appears only at a little distance from the opposite bank; and therefore it must be obvious, that if we draw a line along the surface of the water to any object, and fold up the radiating paper upon it, the lines or the spaces between them will point out the situation upon the surface of the water where the reflection from each object will appear. To the marine painter this may also be of use; by sketching the curvatures of two or three successive waves, and then applying the paper to them, as in fig. 4, he will find that the side of the wave

Fig. 4.



sloping from him reflects the colour of the sky in front of him even down to the horizon, while the curved side opposite reflects the light near the zenith. On this account the colour of the sea is always modified by the colour of the sky. Waves with an increasing gale become ruffled by the wind urging on their surface faster than the motion of the wave itself, which is rather undulatory than progressive; the reflections from these are the same as from the larger wave. The curve facing the spectator (if the sky is clear) is generally a blue line, until it rises to the summit of the large wave, where it is blown over and breaks into a beautiful pris-

Fig. 5.



matic spray, if the sun is shining. It is also applicable to waterfalls, as in fig 5. By sketching the curves of the stream, and applying the paper to it from the point of sight of the person sketching, it will be seen that the top of the stream reflects the colour of the sky behind the waterfall; below this, the zenith light, the colour of the sky behind the spectator, and of the bank on which he is sitting; if the water is curved, then the edges of the curve reflect the dark rocks, trees, and other surrounding objects; if the sun is behind the artist, then the spray will not be pure white, but mixed with sparkling prismatic light.

But these changes in the colour of objects are not confined to white surfaces alone; they influence the appearances of the whole face of nature, which, even to the most superficial observers, must appear under very different hues when seen in the morning, at mid-day, in the evening, or by moonlight. However, since I have got so much involved in the Fine Arts, I shall endeavour to call the attention of those more particularly to this subject (by availing myself of a few jottings in one of my old sketch-books), in tracing the changes in the course of a summer day, in illustration of these effects.

Morning, half-past 3 A.M.—The landscape faint and obscure; tone of colour, blue black. The curtain of night is now beginning slowly to ascend from the eastern sky, which is becoming of a light

* Claud seems to have been well acqainted with the Laws of Reflection, and knew how to avail himself of them so as to produce a pleasant effect in his pictures. His landscapes in the British Gallery, and also in Windsor Castle, seem all to have been painted from sketches taken between the hours of 5 and 8 in the morning, or from 4 to 7 in the afternoon; in other words, with the sunbeams falling upon his landscape at an angle of from 10 to 30 degrees from the horizon. By this means he obtained those sparkling effects from the reflection of the sun light upon the curling waves, and a brilliancy of colour from the effects of the strong reflections and secondary lights contrasting with the lengthened shadows of the trees and buildings in the foreground.

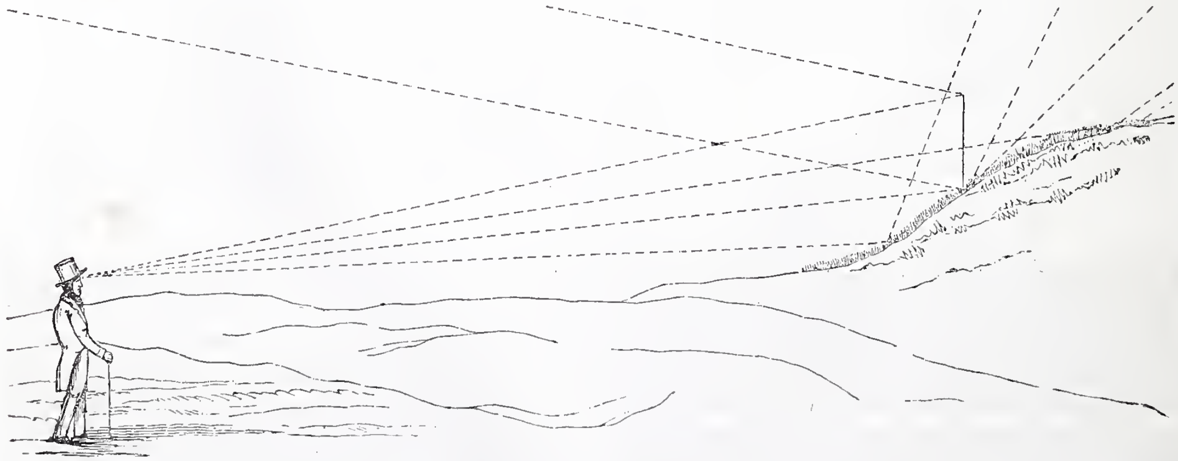
grey inclining to blue; the surface of the sea is also beginning to reflect a faint grey light; close along the eastern horizon a dark lead-coloured stratus or cloud of night still rests 4, A. M.—The sun is now above the horizon, but still behind the stratus, which is now beginning to expand and separate into masses. Through a small opening a spot of golden light is just beginning to shine forth, shedding a stream of glittering rays along the ripple upon the surface of the water; the distant vessels now appear as dark specks, throwing lengthened shadows along the sea. *Half-past* 4, A. M.—The heat of the sun's rays is dissipating the cloud of night, which is now rising slowly from the earth, and breaking up into beautiful towering cumuli, showing a magnificent calm morning. 5, A.M.—The sky near the horizon has now become of a most delicate, light greenish-grey colour, interspersed with beautiful purple and grey cumuli, whose summits are fringed with bright orange and yellow light, while the southern and western horizon is also studded with orange and reddish-brown cumuli and cirrostratus; above these is a thin white cirrostratus, which streaks along the sky; to the south also it has broken into small cirrocumuli, tinged with light orange and purple-brown, and forming a beautiful mackarel sky (as the sailors call it); the lower part of the sky has now become of a cool transparent light blue, slightly inclining to green dark purple near the zenith. As the sun is still hid behind a dark purple-grey cumulus, fringed with light yellow, therefore the colour of the light, from the light blue of the sky and the yellow and orange clouds, is of a greenish hue. The predominating colours of the landscape under this light are deep greens and grey greens sparkling in all the freshness of dewy morn; the distant land to the east is deep purple and greyish brown, while the summits of the hills to the south and west (from their reflecting the direct rays of the sun) appear of a rich greyish-yellow light, with faint shadows of greyish-brown.—6, A. M. The sun is now about 15 degrees above the horizon, but still slightly veiled by a thin light yellow stratus or haze from the vapours of the morning. The landscape appears now in a flood of light, and the fresh deep greens of the foliage are softened and showing more of the yellow and brownish grey tints; the sea also has become a sheet of light from its reflecting the white haze around the sun, while the slight ripple from the morning breeze and the small dancing waves in shore, are all sparkling with golden light; the distant mountains, and the vessels also, from being seen through this haze, are all partaking of this light yellowish-grey tone.

Noon.—The solar heat has rendered the vapours transparent, and now it is mid-day, under a bright and unclouded Italian sky, with which, in June or July, our northern latitudes are sometimes favoured. The foliage has now assumed a warmer tone of colour, slightly inclining to purple; all the shadows are hard and of a dark purple-brown, almost approaching to a black; the outlines of the distant mountains are very distinct, but not sharp and cutting; their predominating colours are dark-greys and greenish-browns, inclining to red, with purple-brown shades, and deep purple-brown furrows. When a cloud forms so as partially to intercept the sun's rays, then that portion of the distant landscape or the hills upon which the shadow falls, will appear of a deep rich blue colour, inclining to purple, from being then only illuminated by the azure light of the sky. If the atmosphere becomes filled with thin fleecy clouds, or if a thin stratus overspread the sky, so as to intercept the blue rays, then the deep azure upon the mountains altogether disappears, and the shadows upon them become of a dusky grey-brown. The hard deep purple-brown shadows of the foreground and middle distance will all become softened—the distant hills also will become of a greyish-green, inclining to yellow.

Evening, 6, P.M.—The tone and appearance of the landscape is now completely changed, the lights and shadows being all reversed. The fresh greens of the morning, and the warmer hues of mid-day, with their dark decided purple-brown shadows, are now rapidly giving place to the yellow, orange, and brown tints of the evening. The prevailing colours of the foliage and foreground now are brownish-greens, reds, and yellows;—middle distance, greenish-greys;—distance, yellowish and orange-greys. 8, P. M. The sky is now beginning to glow with orange light, and the western mountains have become of a deep reddish purple, while the summits of the eastern hills are now lighted up with orange and brown tints. The sun is now rapidly sinking, and the heated vapours which filled the atmosphere and produced such glowing colours, are again concentrating into masses of towering cumuli, glowing with crimson and gold, and sheets of orange and crimson cirrostratus, leaving large openings in the sky which is now becoming clear and beautifully transparent. ¼ past 8 P.M.—The sun has now sunk below the horizon, the golden cirrostratus has become a dark purple-brown, while from the flat ragged bottoms of the dark brown cumuli near the zenith, a deep lurid red still lingers from the last refracted rays of the sun; the dark cumuli and cirrostratus, now deprived of the solar heat, are again condensing and fast sinking to the earth in the form of dews, or to fill the vallies with the cloud of night, again leaving the starry firmament clear and unclouded to the queen of night, which is now nearly full and shedding a brilliant stream of silver light, gradually diverging from the shore to the distant horizon. Every white object now appears like matted silver, while the green and yellow tints of the landscape have become very faint or almost lost, and their shadows dark and almost approaching to blackness; the sky also has become of a dark lead-grey tone, as well as the sea, which is now reflecting its light; but should the sky become filled with light fleecy clouds, then the glistening silver lights and the deep shadows will alike disappear, and all objects then will appear of a sober grey.

Now, from these changes, the colours of objects must, to the practised eye of the artist, appear to be perpetually varying. Perhaps the most correct view we can have of the colours of the landscape is had in the bright interval after a summer shower, when the sun has again broken forth in all his splendour; in these intervals between the showers, the air is in general exceedingly transparent and free from colour, and there is also a profusion of white light reflected from the masses of vapour forming the skirts of the rain cloud which has just passed over. Under this light the colours of the fresh-washed foliage appear extremely brilliant, especially when they are contrasted with the dark bottom of the rain cloud, and the gloom of the distant horizon from the falling rain. In this state of the atmosphere, the landscape may be said to be seen under the most perfect white light.

Fig. 6.



However, we must again have recourse to our paper to explain

some of these appearances. Thus, in the morning before the sun has got above the clouds of the horizon, we find the summits of the western hills illuminated by his rays, and reflecting a pale greyish-yellow light. Now if we place our slip of paper (see fig. 6.) and, from the spectator's eye, fold it upon the slope of the mountain, it will point to the grey light of the western sky. Grey certainly would have been the colour, if the mountain was a smooth or a polished surface, but as the light stems of the bent and the spires of grass which clothe the mountain sides, and from which the sun's rays are reflected, all grow perpendicular, the yellow light of the sun will be reflected from the surface, as from a perpendicular wall, mixed however with the grey light of the western sky; hence the greyish-yellow light on the summits of these hills. Again, we find the landscape in a flood of bright yellow light about 5 or 6 o'clock in the morning, and afterwards becoming of a darker and more purple hue even under the blaze of a meridian sun; this arises from a similar cause; in the morning the sun being only from 10 to 15 degrees above the horizon, a considerable portion of his rays are reflected from their striking obliquely upon the upright fibres of "nature's velvet carpet," and upon the stems and leaves of the shrubs and trees; while at mid-day the almost perpendicular rays of a zenith sun are absorbed and lost among the spires of grass, just in the same manner as the folds of velvet reflect only the light that falls obliquely upon its fibres, while that which falls directly upon the surface of velvet is absorbed or almost lost. Hence the cause of the deep purple-brown shadows of the foliage under a meridian sun and clear sky, during mid-day, the light of the sky near the horizon being the principal colour reflected from the grassy surface to relieve the deep shadows below the trees; and hence also the intense blue or deep azure from the reflection of the sky upon the cloud-shaded mountain in fig. 6. Again, in the evening, the western mountains appear of a purple brown from reflecting the blue rays of the eastern sky, partially mixed with the red rays of the glowing west, while the summits of the eastern hills reflect the orange light of the setting sun, mixed with the cool blue of the eastern sky.

My paper having extended far beyond what I first intended, which was only to show how the folds of paper might be applied to illustrate the principle of reflection, I must draw to a conclusion. However, I beg to throw out a few ideas that have occurred to myself, when noticing some of these effects. We occasionally hear connoisseurs and even artists condemning the ultramarine coloured mountains of some of the old masters of the Italian school, and affirming that the green tints in the completion of the figures in the pictures of Guido, Titian, Carlo Cignanus, &c. although very beautiful, are not like nature. Now I think that these masters of colouring really painted as they saw, and that the deep ultramarine mountains must be an every-day appearance under a bright Italian atmosphere, since I have at times observed in a bright day as intense a blue upon the mountains of Argyleshire. And with regard to the green tints upon the human skin, I believe they arose from the same cause: the blue light of the sky upon the slightly olive-tinted skin of the Italian fair. To test this I asked a young lady who had very much the complexion of the daughters of Italy, to place herself in a proper light at a north-west window, while the sky was free from clouds and intensely blue, then holding up a painting of Carlo Cignanus, I saw the same greenish tints upon the face and neck of the sitter. From this I concluded that under the sultry heat of an Italian summer-day, these masters of colour had painted with the window of their studio thrown completely open; and I must say that, since that experiment, I cannot help thinking that Rembrandt's studio must have looked into a dingy court of brick buildings, and that the room itself has been a dark wainscot pannelled apartment, with the principal light coming from the white hazy clouds of a Dutch atmosphere. Since the colour of the light has such an effect upon both the colour and the shadows of objects, the colour of an artist's studio must also influence his style of colouring. This is suggested as a curious subject, which might deserve to be investigated.

LECTURES ON ARCHITECTURE.

By Professor Cockerell.

LECTURE IV.

THE ÆSTHETICAL PRINCIPLES OF ARCHITECTURE.

The love of fine art, and the lively discussion of its principles, which occupied the wits and the courts of Italy in the 15th, and 16th centuries, employed the solitary reflections of literary philosophers in the 18th; and in 1730, Baumgarten suggested the title of æsthetics, by which these studies have been designated ever since, and many works remarkable for ingenious criticism, learning, and taste, have resulted. These may be ranked in two classes. The first resolves the questions of taste directly into an original law of our nature, implying senses by which the qualities of beauty and sublimity are perceived and felt as their appropriate objects; it is this species of hypotheses to which artists and amateurs chiefly resort. The second class of hypotheses arises from the opposite view of the subject; resisting the idea of any new and peculiar sense distinct from the common principles of our nature, this class supposes some one known and acknowledged principle or affection of the mind to be the foundation of all the emotions we receive from the objects of taste, and resolves them into some more general law of our intellectual or moral constitution. Thus Socrates and Hume, and others, resolve them into our sense of utility—Aristotle and St Augustine, into order and design—Diderot and Allison into relation and association. But though in such discussions we recognise many truths, the partiality of individual views renders them often dangerous.

> When a philosopher can find
> Some fav'rite system to his mind,
> In every point to make it fit,
> He'll force all nature to submit.

Language itself fails in defining those phenomena which elude ordinary observation, and even when it approaches definition, the measure of quantity, and quality, and circumstance, can alone be adjusted by the magician Genius.

The æsthetical principles of Architecture, as handed to us from the Greeks by Vitruvius, concur with the notions of ancient philosophy, and have not been controverted by the modern; and though subjected of late years to some rude attacks, they have never been superseded, and we can follow no better text-book in the consideration of our subject. Those principles apply to every style and invention of architecture which the world has hitherto known; they belong to our physical and intellectual nature, and will never change but with an alteration in these.

When the works of Vitruvius were first discovered, they were accounted a revelation to the craft, and called "divine" by Sulpitius, the first translator; and nearly two hundred years after, Perrault, in his translation, calls them "a very singular piece, and an inestimable treasure in the opinion of the learned." Eighteen translations, in forty-one editions, are enumerated to this day. In 1807 the philologist Schneider republished Vitruvius. "My whole scope," says he, "has been to purify the text, so as to enable men learned in Art to reconstruct and understand the theories of Vitruvius, hitherto obscured by interpolations, and vicious translations." But he detracts from the merit of his work by a severity of criticism as uncandid as it is derogatory to the character of his author. He declines his apology, as "writing neither as an accomplished philosopher, an eloquent rhetorician, nor as an expert grammarian, but as an architect laying down rules useful to those who build." He calls his language obsolete and plebeian, accuses him of pride and envy, and rates him as a morose, inept, infirm old man, querulous and vulgar. But Schneider was the less justified in such treatment, as being weak upon those points in which his author was most strong; for he says, "on architectural subjects, or that which has to do with the subtleties of the art, and the questions and disputes concerning them, I neither could nor would have anything to say." So that the science has received no direct advantage from the labours of Schneider, and yet how much was to be done might be understood by ten discoveries in confirmation of the theories of Vitruvius, made within a few years, and chiefly by Englishmen, cited by the Professor in his previous course on the literature of the art. Such discoveries suggested the desirableness of a new English edition of Vitruvius, as highly honourable and useful to this country. The last, by Mr Gwilt, is a very useful one.

The slanders of Schneider had been adopted in this country with little honour to the parties, and no advantage to architecture. Vitruvius remained the father of our art, and was entitled to our respect, as the text-book of our studies.

Having been appointed surveyor to the warlike engines and stores of the empire by Augustus, Vitruvius was endowed with leisure; and very probably was instructed to collate the Greek authors on our art, whom he enumerates, and who were collected and deposited in the magnificent library instituted at that period

He appears then with singular advantage as transmitting the well digested and received principles of the greatest masters who had thought and written on architecture, to modern times; and the principles thus derived directly from the Greeks merit our closest attention.

But a few preliminary observations on external forms, in detail and in general, were to be made. The universality of certain primordial forms in all styles, favours the notion of innate ideas—the cube, the sphere, the ellipsoid in solids; the lozenge, the wave, cymarecta, and cymareversa, the serpentine, the ovalo, the spiral, the volute. Gradation or diminution of forms is common to the art of all times and people.

The pyramid is universal, from the compressed to the acute. Such is the charm of the pediment, that "in heaven, where we may not suppose it to rain," says Cicero, "the pediment will surely be found;" so in mountains, trees, and fixed bodies, in which the laws of statics are observed, the pyramid prevails; except in those forms in which dynamics demand a different structure. The pyramidal inclination of the sides of buildings observed in Egyptian, Hindoo, Gothic, and Mexican architecture, has, by the happy discoveries of late years, been proved to exist in Greece also; and the inclination of the axis of the columns at the sides of temples (enjoined by Vitruvius, lib. iii. c. 3, long disputed,) is now beyond all doubt; thus the pyramidal inclination of buildings is proved to be a universal principle.

Gradation of columnar forms, as in the limbs of animals, and in vegetable productions, is universally approved; the cylinder, the leg of an elephant, are justly repudiated: "small by degrees, and beautifully less," has been denied by an eminent critic (P. Knight), "because," says he, "the same is large by degrees, and beautifully bigger;" but however smart the reply, it does not controvert the principle. It is, however, to be observed, that such forms should diminish *from the eye*, as a column does above the horizon, and the leg of a chair or table below it.

The Doric cymatium, the cymareversa, the ovalo, the cavetto, or hollow, are all calculated to express strength, as robust, and appearing to sustain. The Lesbian cymatium, the cymarecta, in all its varieties, has not the same purpose, (namely, to sustain,) and is suited to the more elegant orders. The principle of the application of mouldings for beauty, is the opposition of the curved to the straight surfaces, as well for light and shade as form; and the proportions and oppositions of such forms constitute the art of profile—a most difficult grace of architecture; for by this that variety of form and grace may be given which the primary architectural masses and proportions do not admit of. Variety in the *details of sculpture and profile is essential* to the relief of that rigorous geometrical order, which the larger features of architectural composition impose: in all the arts, and even in architecture, variety is an all-important principle, provided the masses are undisturbed. Shakspeare describes Cleopatra as chiefly admirable for this quality:—

> Age cannot wither her, nor custom stale
> Her infinite variety.

The Greek profile in general (more particularly in the Parthenon) is incalculably superior to any other in gradation, quantity, delicacy, and expression, and should be the student's constant study. It was the observation of the human, animal, and vegetable forms, by the sculptors of Greece, which gave them that acknowledged superiority. The enrichment of these with homogeneous ornament, was no less remarkable, and deserves an especial treatise. In fact, the elements of architecture, in the orders and their profile, constitute the peculiar excellence of Greek architecture, which, as we have seen in history, did not extend to the composite and voluminous combinations which subsequent ages adopted.

Having thus adverted to individual forms as applied to detail, the Professor remarked upon general forms as applied to the composition of buildings. The system which prevailed in ancient times, of building "in large stones and costly stones, even great stones," to which allusion has been made, doubtless contributed much to the universal adoption of horizontal forms of building. But this tendency, thus imposed by the mechanical construction, seems also to have been an abstract principle of taste, which was consulted best by the contrast of the long horizontal form with the (generally) vertical outline of the country in which they were employed. When the traveller, passing through a mountainous region of rugged outline, discovers through some gap the horizon of an extended plain, or of the ocean, a sublime sensation is experienced. In such a country the rocks and mountains afford elevations compared with which the works of man are insignificant. The temple is planted on the precipitous eminence, and it attains at once the elevation of St Peter's or St Paul's. So placed, the Doric members should be massive, simple, and few; the parts broad; it seems to have grown spontaneously from its rocky bed, and to partake in its monolithic masses of the stony aboriginal material on which it is established. Its horizontal outline and regularity of order are admirably calculated to contrast with the surrounding scenery of vertical and irregular forms.

On the other hand, when the road winds through interminable plains, the traveller recognises the sublime in the contrast of vertical forms of architecture: for this reason, it may be presumed, the Babylonians in the plains of Assyria proposed to "build a city and a *tower* whose top may reach unto the heavens." In the flats of Venice, in the Netherlands, in the champaigns of France and England, especially in the low lands of Lincolnshire and the north, the spire and the tower are found to be the effective and all-sufficient means of obtaining that sublime which man desires in architecture—that conglomerate composition of small stones which a man may carry up a ladder on his back, are in character with the style and the manner of building.

But, recurring to the theory of the art, we find that Vitruvius (lib. i. c. 11,) lays down six principles: order, as addressing the understanding; disposition, as addressing the eye; proportion; symmetry; consistency; and distribution, or economy.

Order, as evincing design, whether geometrical or moral, affects the mind with the sentiment of sublime. Whoever considers the movements of the planets, and understands the laws of their velocities, the curves which they describe, the relations of the periods of their revolutions and their distances, will find himself wrapt in a sublime pleasure, and will recognise a divine beauty of order; but if he turns his contemplation to the fixed stars, in which he can trace no order, and which appear to be disposed fortuitously, the same pleasure is by no means felt.

When a curve is formed by a certain rule and a constant law, as the semicircular vault and the apsis at the end of a church, both which shall be concentric, a great satisfaction is experienced: if these are elliptical, the rule and law are less easily understood; but much more, if eccentric segments are employed, the want of that uniformity is felt, and a kind of violence is done to the eye and understanding. So the rhomboid, and much more the trapezium, displease by their anomalous and unequal angles. No predetermined counsel, order, or industry are evinced, and the essential sense of order is dissatisfied.

If the philosopher finds any natural production—a stone, or a root—assuming the regularity of a geometrical form, he judges it worthy of a place in his museum: such is the love of order. Individuals in a mob have neither force nor effect, but ranged in regimental order they acquire a new quality. So trees planted in avenue have, in many situations, an effect superior to the forest. The desire of imparting variety to his work, often misleads the architect from this important principle of his art; forgetting that his building is to derive its chief effect from the contrast of its regularity and order with the surrounding irregular objects and scenery, he seeks, too often, to make his own building his picture, and to ingraft upon it that variety which the scenery ought to supply. Thence picturesque architecture, which has diverted the student from the ancient principles, universal amongst the old masters. Succession and repetition of impression by parity of objects, by regularity and order, the isometrical colonnade or Gothic arches of the nave, or equidistant windows along an unbroken front, have more energy and effect than all the varieties of such features that can be contrived. The surrounding irregularities make order tell by their contrast.

Vanbrugh was remarkable for this quality, and he knew at the same time how, by the composition of his parts, to produce, from certain points of view, the utmost variety of combination and picturesqueness, while, from others, the whole was perfectly regular.

Perrault observed order rigidly, as did Wren; while by the contemporary fashionable architects amongst the Italians, it was totally abandoned, as may be remarked in the front of St Peter's, and in the works of Bernini, Borromini, and Maderno. Columns in groups, or at irregular distances, broken entablatures, for the sake of a repetition of profiles, curvilinear

fronts, and such scenery as belongs to painting, established the novelty of picturesque architecture—a solecism in art—and a contradiction in terms, unless by combinations from certain points of view as above.

If we call to mind the fact, that the greatest architectural efforts have usually followed periods of political and moral disorder, we may recognise in such works that natural love of order which revolutions and tumults have denied. Certain it is, that after a long period of civil tranquillity, architectural efforts, especially of regular order, have ceased to be fashionable, and the picturesque or the irregular is resorted to as a change.

Disposition or composition of the various features of an architectural work, is the second principle laid down by Vitruvius. It consists, says he, of the idea of the ichnography; the idea of the orthography, or elevation; and the idea of the scenography, or view in perspective, taken on the angle. "These," continues he, "are the result of thought and invention; thought, full of attention, application, and vigilance, accompanied with *delight;* and invention, which is a solution of difficult problems by new applications seized with *promptitude.*"

Thus he proceeds as Nature does; putting the purpose or the plan *first,* to which the figure of the object adapts itself *secondly,* and thus each composition displays peculiar features; and the appearance of his buildings would be as various as their purposes; whereas modern architects often reverse the method, and they constrain the plan to a preconceived orthography. How otherwise is it that we recognise the master the moment we see his work? The orthography ever the same, and the plan adapting itself as it can: so we commonly put the cart before the horse.

But the exact conception of the ultimate effect of the building, the realization of the prophetic vision of the architect, are of extreme difficulty, and subject to lamentable disappointment. They can be attained only by great knowledge of perspective, and by careful models; and the greatest masters have been most remarkable for their reliance on such means.

"The architect," says Wren, "ought, above all things, to be well skilled in perspective; for everything that appears well in orthography may not be good in the model, especially when there are many angles and projectures; and everything that is good in model may not be so when built, because a model is seen from other stations and distances than the eye sees the building. But this will hold universally true, that whatsoever is good in perspective, and will hold so in all the principal views, whether direct or oblique, will be as good in great; if this only caution be observed, that regard be had to *the distance of the eye in the principal stations.*"

In this last particular the methods of the different masters have varied materially. For instance, Vanbrugh always supposed himself at a distance of 500 to 1000 feet from his buildings; consequently his sky line and contour are well studied, but his details wholly neglected, and the pleasing effect of his buildings lessens in approaching them; whereas Adams supposed himself from 50 to 100 feet only from his buildings; consequently they have no contour from a distance, but are full of elaborate detail on the approach.

The visual angle, extending at most to 45°, should be carefully applied to the points of distance; and the scale of the drawing or study should be correctly adjusted to this distance, so that no misconception should arise. A study for a building to be seen at 100 feet distance only, will be on a large scale, and occupy the whole height of the paper; whereas, seen at 500 feet, it may be only one-fourth that size.

The Greeks were consummate masters of this branch of optics, as we should doubtless have known had Aristotle's work on Taste been preserved to us. The terms "synoptic" and "eusynoptic" correspond with the points of view which all their arrangements were calculated to afford.

The Parthenon and the temple of Jupiter Olympus—indeed, almost all the great temples—were approached on the angle, the peribolus and the propylea, by which they were enclosed, concealing great part of them, until they could be contemplated to the utmost advantage from a synoptical point of view. The plans of Palmyra and Balbec, and those of Rome, preserved to us by Palladio, are lessons, in these respects, demanding the most careful attention.

It is obvious that Street Architecture, being seen chiefly in flank, should be treated otherwise than buildings at right angles with the point of view, as triumphal arches, or terminations to the vista.

In the fifteenth and sixteenth centuries, perspective delineation became a new art in the hands of Lombardi, Bramante, Peruzzi, Raphael, and lastly, the renowned Pozzi; and though Vitruvius assures us, that in the fifth century B. C., Agatharcus wrote a treatise upon Perspective, it is probable that the ancients never arrived at the skill attained by those masters.

But perspective calculation applied to Architecture, and the adjustment to the point of view, was undoubtedly better understood practically by the ancients than ourselves, as their remains abundantly prove. The vista which shortens the length, and discloses the end at once—the exposure of the entire object staring from a distance as well as near—the placing colossal objects in colossal places, are all modern mistakes. The temple at Luxor, the colonnade at Palmyra, are deflected in angles, so that the bounds are concealed, the successive columns disclose themselves by degrees, and the length seems interminable. The temple is partially hidden, and excites the imagination from the promise of its roof, entablature, and capitals, until it is permitted to be seen in its overwhelming majesty.

The Columns of Trajan and Antonine are placed in confined positions, and the effect is tenfold.

Palladio was remarkable for the adjustment of his building to the position, of which the Town Hall at Vicenza is one of the most remarkable examples; and the surprise and admiration of the traveller who has known that building only in the orthographic engravings, can never be forgotten.

Vignola is said to have made his studies of his buildings at the points of view from which only they could be seen.

It is quite certain that Sir W. Chambers was less master of this part of his art than of many others. Any one visiting the front of Somerset House, in the Strand, is satisfied with its scale and sufficiency in all respects; but when he enters the spacious quadrangle, and looks on the back of the same building, he experiences some disappointment; he finds the scale too small for the size of the quadrangle: but much more, when he observes the same proportions from the opposite side of the river, he deplores their littleness and want of mass and feature, the petty dome in the centre, and the confusion of chimney shafts which disfigure the roof. Had Vanbrugh disposed the river front, we should have seen those chimney shafts united in towers; the whole outline or sky-line would have been marked and varied with emphatic features, suited to the scale of the river, and the majestic position given to the building.

"It is the part of a wise man," says Alberti, "to have the idea of his work well fixed in his imagination. The ancients, therefore, not only by perspectives, but by models of the whole, and of parts, submitted their works to practised men, before they laid a stone. Such models should not, however, be pretty toys, in which delicacy of workmanship draws the attention from the merit of the design. Finally," continues Alberti, "when the model satisfies the architects and practised judges, I recommend that there should be no hurry to begin, but, if possible, time should be allowed that the conceit of the design may cool; when, having laid aside the natural overweening affection for your own production, you may judge more justly of its effect. Time discloses many counsels for the advantage of our undertakings; and many defects, which at first escaped attention, at length become apparent." Scamozzi used to say, that pretty little models were like pretty little birds, no one could tell whether they were masculine or feminine; but if made large, you might then discern which was an eagle and which a crow.

Vitruvius, lib. vi. c. 11, and lib. iii. c. 111, refers to optical effects.

Proportion is the third principle set forth by Vitruvius, the most difficult and the most precious to the architect, and no less a golden rule in his art than in that of the arithmetician. Symmetry, which is the fourth principle of our author, is, by a vulgarism, often mistaken for proportion; but the etymology defines its meaning, as correspondence or parity of parts on either side a centre; at most it may signify proportion of aliquot parts. No part of Architecture has occupied the speculations of the ingenious more than proportion, and those who have not found the analogy of the human form, as set forth by Vitruvius from the Greeks, sufficient, have endeavoured to find a more certain analogy in the laws of musical sounds: Blondel, Ouvrard, and others, may be consulted on this point.

To the artist observer of the proportions and forms of animal natnre, the Greek analogy seems to develop the science of proportion in the comparison of animals of the same genus, but of various species, sufficiently to show that beauty resides in inequalities ; the measure of these inequalities is, indeed, not so easily defined; but the establishment of the fact may help the architect to some valuable conclusions.

Thus, if we divide the human profile, the forehead, the nose, the upper lip, and the chin, into equal parts, we have ugliness : the profile of the Apollo presents these parts in *inequalities*, and upon the nice variety of these beauty depends.

The satyrus, or baboon, is ugly, compared with the man: amongst many other reasons, for this, especially to the architect, that his proportions approach equalities. The baboon is six heads high ; his arms equal the entire length of his body and legs ; the subdivisions of the arm, the hand, the fore-arm, and the os humeri, are nearly equal ; so also the foot, the leg, and the thigh. If these proportions are compared with the human form divine, in which they are all in different and unequal lengths, the cause of beauty will be at once apparent. The human figure is eight heads high, and is inscribed by Vitruvius in a square, whereas the baboon is inscribed in a figure of less beauty, namely, a parallelogram of 6 by 11, such is the length of his arms. Thus, again, if we inquire why the ass is so inferior to the horse, we shall find the same answers. The one is little more than 2 heads to the shoulder, while the horse is $2\frac{1}{2}$; the ears of the ass approach equality with the head or neck. The scapula to the os humeri, in the ass, 4 to 5, in the horse is 4 to 6 ; the metacarpus to the radius, 3 to 5 in the ass, is $2\frac{1}{2}$ to 5 in the horse.

The Professor exhibited drawings in illustration of these remarks, and stated, that the same relations applied to vegetable nature, and that beauty there, also, would be found to reside in inequalities ; and he proceeded to show, that orthographic equalities in the vertical features of Architecture, both in the divisions of floors and orders, and in details, were always evidences of the decline of taste. In Greek profile, it would be found universally, that inequalities constituted their charm ; in the Roman they were not so nicely observed ; in the Byzantine, the plain and moulded surfaces approached equalities. So in Gothic architecture, the period of the thirteenth was far superior to any other in tbis respect ; of which the transept of Beverley Minster, and the order of Salisbury Cathedral, were beautiful illustrations. So in every other architecture, and in forms of all kinds. In fact, from the long and the short, the dactyle and spondee, hexameter and pentameter, sapphics and iambics, the very term *εὐρυθμία*, (proportion), used by the Greeks, was derived.

Under the fifth head, Consistency, lib. i. c. 2, Vitruvius tells us, that circumstance, custom, or fitness, and Nature are to guide us. Temples to Jupiter Cœlus, the sun and moon, are to be hypethral, because these divinities are known to us by their continual presence night and day. Doric temples are to be erected to Minerva, Mars, and Hercules, on account of their masculine character ; Corinthian is proper to Venus, Flora, Proserpine, &c. ; Ionic, as the medium order, is applicable to Juno, Diana, and Bacchus : all these, says he, bear an *analogy* to the dispositions of the deities.

Again, in lib. iii. c. 1, he says, " the design of temples depends on symmetry, the rules of which architects should be most careful to observe : symmetry arises from proportion, which the Greeks call ἀναλογία." He then proceeds to describe the proportions of the human figure in detail, and remarks its correspondence with the geometrical figures, the square and the circle : even the measures used in buildings, the digit, the palm, the foot, the cubit, called by the Greeks τέλειος, prove the analogy of architecture (continues he) with the human proportions.

In lib. iv. c. 1, Vitruvius describes the origin of the Doric, Ionic, and Corinthian orders, as derived from the proportions of the man, the matron, and the damsel, by analogy ; and although these analogies have been regarded by some as fanciful, their æsthetical propriety is more intelligible to the artist than their definition by language to the logical reader. For instance, the ancient Doric, from five to six diameters in height, though low in its proportions, assumes a dignity in its concentrated strength and solidity, its rapid diminution, and its wide-spreading cap, which no one who has viewed it at Pœstum and at Corinth can ever forget.

When Homer describes Priam as identifying the Grecian leaders from the walls of Troy, he is made to inquire of Helen,—

What's he whose arms lie scattered on the plain;
Broad is his breast, his shoulders larger spread,
Though great Atrides overtops his head ?

Had Homer (always a painter) confined his description to the stoutness and the shortness of Ulysses, we should have been at a loss for his heroic dignity ; he might have been a tub or an alderman; but the " broad shoulders and his spreading breast" imply the rapid diminution of the waist, and the same healthful and vigorous character through every limb ; and Ulysses stands before us in all the energy of the Grecian hero—

Though some of larger stature tread the green,
None match his grandeur and exalted mein !

no such peculiarity is attributed to " the great Atrides ;" the tall is not compatible with this rapid diminution : whenever these qualities, therefore, are affected, as in the Parthenon, the temple at Nemea, or in the Roman Doric, the upper diameter bears a larger proportion to the lower. So in the matronal or the medium proportion, the gradation of form is much smaller ; and in the juvenile Apollo or the young damsel, the diminution of the limbs is still less observable ; and the Ionic or the Corinthian are proportioned accordingly. In the details the same analogy is observed ; the mouth, the eye, and the features of the Hercules are as susceptible of delicacy as the Doric echinus is of its small fillets and its fine contour.

The matronal or medium demands a sober ornament, and the Corinthian all the young elegance which the acanthus and the graceful Lesbian profile can communicate.

Thus the tall, the short, and the slender, are all types of proportion in their proper places ; their *excess* makes them the awkward and ungainly, the clumsy and shapeless, and the thin or meagre ; and there is no other course by which they can be rightly imbodied, than by the careful and intelligent observation of those types, as exhibited in the works of Nature—in the animal and vegetable kingdoms.

In this respect, taste, like wit, consists in discovering resemblances and unexpected congruities.

The history of the works of genius illustrates abundantly the reference to analogy in the science as well as in the art of architecture. Smeaton, in his work on the Lighthouse at Eddystone, after describing the former ones, and showing their defects, proceeds to explain his original conception of that celebrated work. " On this occasion," says Smeaton, " the natural figure of the waist or bole of a large spreading oak presented itself to my imagination. Its top, when full of leaves, is subject to a very great impulse from the agitation of violent winds ; yet partly by its elasticity, and partly by the natural strength arising from its figure, it resists them all, even for ages. It is rare that we hear of such a tree being torn up by the roots. Let us now consider its particular figure. Connected with its roots, which lie hid below ground, it rises from the surface thereof with a large swelling base, which at the height of one diameter is generally reduced by an elegant curve, concave to the eye, to a diameter less by at least one-third, and sometimes to half, of its original base. From thence its taper diminishing more slow, its sides by degrees come into a perpendicular, and for some height form a cylinder. Now, we can hardly doubt but that every section of the tree is nearly of an equal strength in proportion to what it has to resist ; and were we to lop off its principal boughs, and expose it in that state to a rapid current of water, we should find it as much capable of resisting the action of the heavier fluid, when divested of the greatest part of its clothing, as it was that of the lighter when all its spreading ornaments were exposed to the fury of the wind. And hence we may derive an idea of what the proper shape of a column of the greatest stability ought to be, to resist the action of external violence, where the quantity of matter is given whereof it is to be composed."

Sir C. Wren has given another fine example of this kind of analogy. In the vast practice which the fifty churches of this metropolis and the examination of all the authorities which he had occasion to consult had given him, he reflected that the hollow spire, which he had seen and built in so many varieties, was after all but an infirm structure ; and he sought that model which should enable him to impart to it the utmost solidity and duration. Simple was the original from which he adopted his idea. He found that the delicate shell called turretella, though extremely long, and liable to fracture from its base to its apex, by the action of the water amidst the rocks, was rendered im-

pregnable by the central column, or newel, round which the spiral turned. Therefore, in his spire of St. Bride's, he establishes the columella in the centre, round which he forms a spiral staircase to the top, issuing on stages of arched apertures; thus giving us, if not the most beautiful, certainly the most remarkable and enduring of any spire hitherto erected.

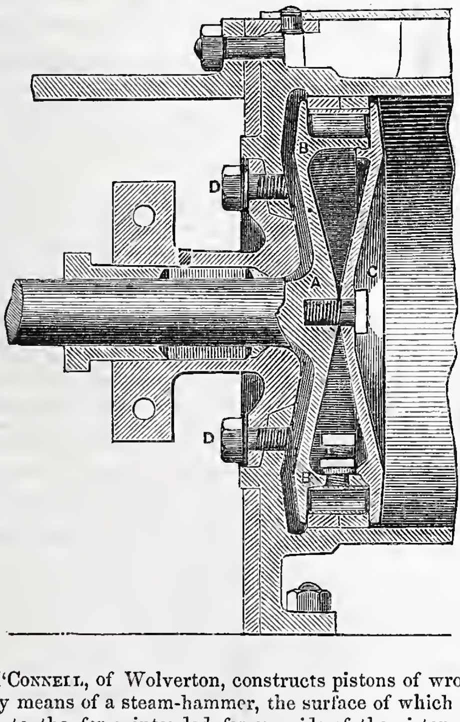
One more instance equally remarkable may be given. When Brunelleschi was charged with the erection of the dome of Sta. Maria, at Florence, of nearly equal diameter with that of the Pantheon, but at more than twice its height from the pavement, upon a base raised on piers, and by no means of the strength and cohesion of the original model, the Pantheon, it was apparent that in giving it the same solidity, the weight would be unsupportable on such a foundation. How was this object to be accomplished? Brunelleschi was an observer of all Nature's productions, and he reflected that the bones of animals, especially of birds, possessed solidity without weight, by the double crust and hollow within. But above all, he remarked that the dome which completes the architecture of the human form divine, was constructed with a double plate, connected by the light and fibrous, but firm walls of the hollow cancelli, so that strength and lightness were combined in the utmost degree. Brunelleschi followed this model in his dome of Sta. Maria (in the manner displayed in a large section exhibited) ; and the traveller now ascends to the lantern between the two crusts or plates forming the inner and the outer domes.

Michael Angelo adopted this contrivance in the dome of St. Peter's; and almost all the subsequent domes are upon the same idea.

The Professor pointed out these instances of analogy as sufficient to show that the architect might thus avail himself of the whole range of Nature's works, and that the universe furnished him the inexhaustible models from which his inventions might be drawn.

WROUGHT-IRON PISTON APPLIED TO LOCOMOTIVES.

BY MR. M'CONNELL, ENGINEER, WOLVERTON.



Mr. M'Connell, of Wolverton, constructs pistons of wrought-iron, by means of a steam-hammer, the surface of which corresponds to the form intended for one side of the piston, while the shape of the anvil corresponds to that of the other face of the piston, as represented in the figure.

The inventor makes several varieties of these pistons. Generally, the piston-rod is formed in one piece with the body of the piston itself, as in the example before us. Sometimes, however, he makes use of tubular rods, which screw on a cylindrical spindle projecting from the body of the piston.

A is the body of the piston, which, as we have stated, is forged of one piece with its rod. This body is armed with an annular projection, B, round which the segments are disposed. The disc, C, is also furnished with a low annular projection, which screws on B.

The two pieces, A and C, have a concave and conical form, such that they come into contact at their centre, where they are united by a screw.

The lid of the cylinder is fixed by screws, D, and may also be of wrought-iron.

HUGHES AND DENHAM'S PATENT CIRCULAR WARP AND WEFT LOOMS.

The principle of this invention, patented May 7, 1853, is the weaving of fabrics by means of circular machinery, the feeds being arranged in sections round a circle, the upper surfaces of which are formed into a circular groove or channel, on which the bobbins for carrying the weft-threads traverse. The revolution of the bobbins is produced by the rising of the reeds, through the intervention of friction rollers attached to the central shaft; the outer ends of the reeds being centered on a wire or pins attached to the framework. The warp-threads are passed through heddles pierced through levers, which are acted on by cams attached to the main shaft, so as to cause the said warp-threads to cross and recross one another, and thus to open the sheds for the passage of the shuttle or shuttles. This arrangement will be understood by a brief account of the mechanism shown in the annexed drawings.

Fig. 1 is a sectional elevation of so much of a circular loom as is necessary to explain the invention. A is the central shaft, the lower end of which turns in the step, B, upon the base plate, C. D is a bent lever, one end of which is centered in the ring, E, which surrounds the main shaft. The upper ends of these levers are connected by the pin, *a*, to a second series of bent levers, F, which are held by a wire or pin passed through the slot, *b*, and supported by the ring, G. H is the heddle-eye, pierced through the lever, F, there being one heddle-eye for each lever in the circle; and I the warp-threads, which are wound round the warp-bobbins, K, and, after passing between the tension rollers, L, are passed through the heddle-eyes, and carried up to the disc, M, round which the work is formed.

N is a friction roller, centered upon the spindle, *c*, attached to the main shaft, and revolving with it. O are the reeds centered upon the pin or wire, *d*, attached to the general framework of the machine. These reeds have cut in them the groove or notch, *e*, which forms a tramway for the passage of the shuttle-carrier and shuttle. This shuttle-carrier is composed of a small plate, *f*, having friction wheels, *g*, in each end, which traverse in the notches in the reeds, O. *h* is the shuttle, upon which the weft-threads are wound. This shuttle is supported and turns in brackets upon the plate, *f*. P is a friction roller revolving upon the spindle, *i*, attached to the main shaft, A, which, as it rotates, lifts the reeds so as to form an inclined plane, and thereby the shuttle is made to advance and lay the weft-thread between the warp-sheds. The action of this machine is as follows :—Upon motion being given to the central shaft by means of the bevil wheel, Q, geared into by the pinion, R, on the shaft, S, driven by the crank-handle, T, the friction wheels are caused to revolve, and by means of the wheel, N, acting upon the levers, D, and through them upon the levers, F, they are alternately thrust outwards, carrying with them the warp-threads. Upon the levers, D, being released from the roller, N, a helical spring, U, which is attached at one end to a projecting pin upon the end of the levers, F, and at the other

end to the general framework, causes the levers, F, to be drawn back towards the centre of the machine, and so to cross the warp-threads, and admit of the shuttle passing between and laying the weft to form the fabric. The levers, D, may, if desired, be arranged in sections, so that upon the passage of the friction roller, N, they are alternately thrust forward and drawn towards the centre, whereby the warp-threads are caused to cross and re-cross each other for the passage of the shuttle.

Fig. 1.

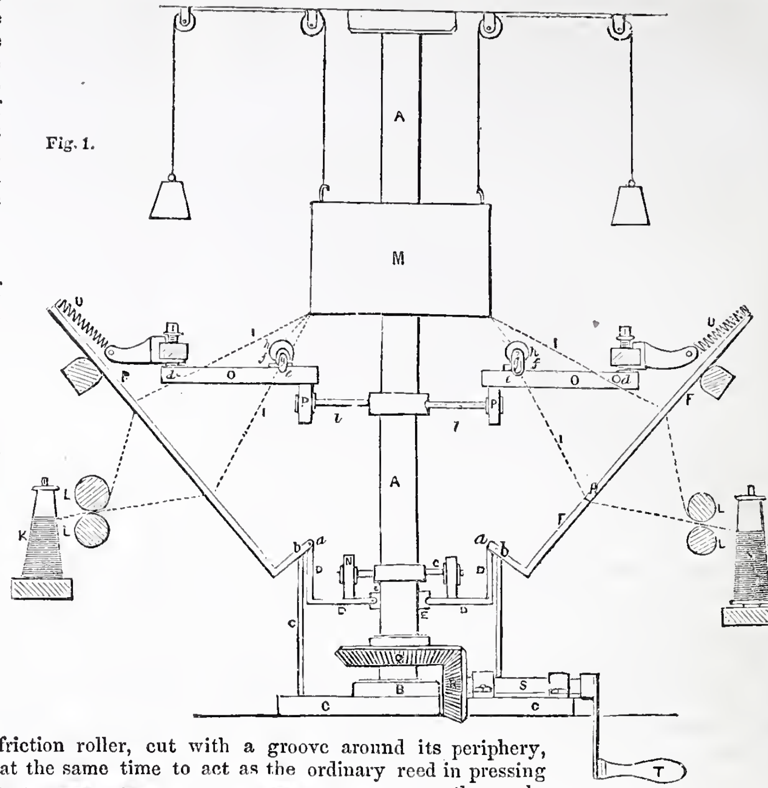
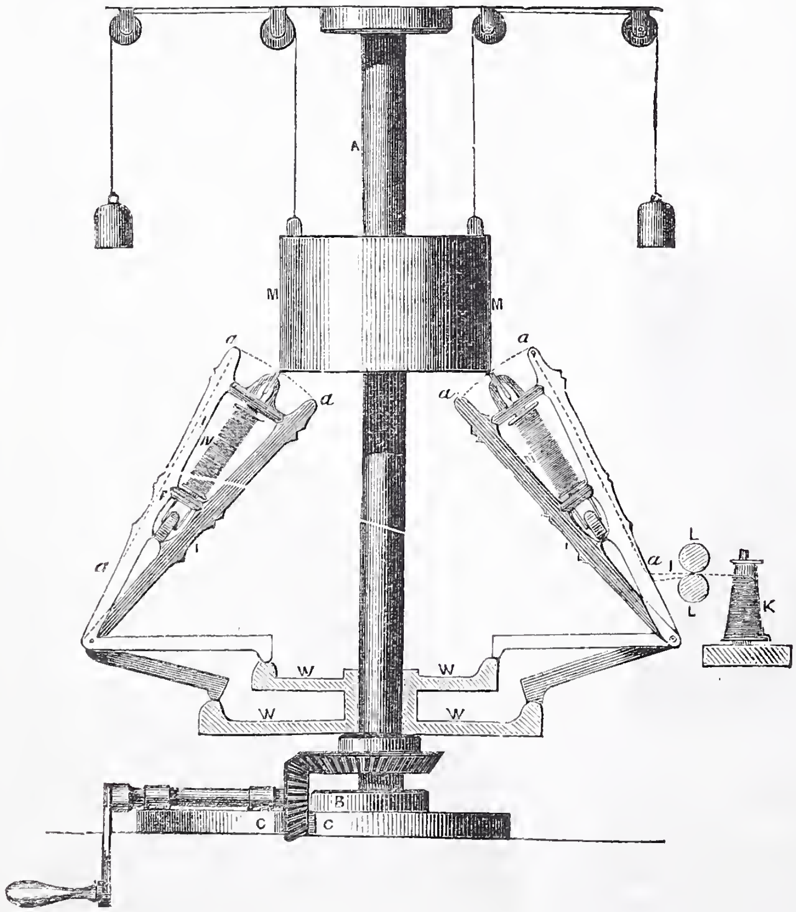


Fig. 2 represents a similar section of a modification of a circular loom, in which the reeds, O, are dispensed with, and the inclination of the levers, F, is reversed, the shuttle being supported in notches or grooves cut in the ends of the levers, F, and caused to revolve by the crossing and recrossing of the levers behind the shuttle. W W are the cams attached to the main central shaft, and revolving with it, for causing the levers to cross and re-cross each other for opening the warp-sheds for the passage of the shuttle for laying the weft-thread. I I are warp-threads, which are wound round the warp-bobbins, K, and after passing through the tension rollers, are passed through heddle-eyes, *a a*, in the levers, F, by which the threads are carried up to the disc, M, where the work is produced.

The shuttle, N, has at top a small friction roller, cut with a groove around its periphery, which serves to lay the weft-thread, and at the same time to act as the ordinary reed in pressing the work.



The lower end of the shuttle has also a friction roller, which runs in a groove formed in the levers, F, so as to form an abutment for the friction roller, *n*. The disc, M, is caused to rise as the work is produced, by any of the ordinary methods employed in the circular knitting-frames.

The advantage claimed by the inventors for this arrangement is the large quantity of weft-threads which may be continuously laid on, in consequence of so many weft shuttles working at once. It is stated that fifty-four weft-threads may be laid in a loom occupying a space of only one yard in diameter; that this loom may be applied with advantage to the production of materials for forming seamless garments; and that it will be found to surpass the power-loom in the weaving of both plain and figured fabrics. It certainly displays a great deal of ingenuity, and seems to be a great improvement, both in economizing space, and in still further dispensing with manual labour. Taken in conjunction with the novel sewing machine, the electric jacquard loom, and other recent applications of machinery for purposes and by agencies equally startling and unprecedented, it seems to remind us that a time is approaching when human labour will cease, when the world will move by machinery, and nothing remain for the exercise of human activities but intellectual effort.

SKETCH OF THE METAL MANUFACTURES.

CHAPTER II.

THE CONVERSION OF IRON INTO STEEL.

In our first chapter we traced the manufacturing progress of iron from its rocky bed in the mine to the blast-furnace, and thence to the foundry and the forge. We described the process of *roasting* the ore, the construction of the blast-furnace, the nature of the hot-blast, the casting of iron into "pigs," the processes of founding or casting in general, and those that are employed for the production of wrought-iron—the puddling-furnace, the shingling-hammer, the balling-furnace, the puddle-rolls, &c., by which means the pigs of iron are gradually wrought and rolled out into the form of bars or sheets. When the metal has been brought into these forms, the ironmaker's work ceases, and the bars or sheets are ready to be applied to purposes which may indeed be said to be innumerable.

These are of two great classes, according as the metal is used in the state of iron, or undergoes that peculiar modification which gives to it the name of *steel*. This modification, and the production of cutlery resulting from it, will next engage our attention. The conversion of iron into steel will form the immediate subject of the present chapter.

"From what country and in what form is *steel* procured?" We should probably be correct in surmising that this question has occurred to many who are familiar enough with the appearance and the use of steel. Whether this valuable metal is a simple substance, forming narrow veins in hard rock; whether it occupies thick layers or beds beneath the earth's surface, like coal and rock-salt; whether it is found in rounded lumps or crude masses, scattered irregularly in mining districts; whether it is formed chemically from a mixture of several different substances, by the aid of heat and liquefaction, and with all the appliances of retorts, crucibles, and furnaces; whether it contains iron, or *is* iron, and how (if it be iron) the change from one form to the other is brought about; whether there are any steel-mines, and, if so, where they are situated—all these are points which are by no means so generally understood as they deserve to be.

Steel is a combination of iron and carbon. Black-lead, of which drawing pencils are made, is also composed principally of iron and carbon. Cast-iron, too, is a compound containing pure iron and carbon. The striking differences between these three substances arise in a twofold manner—from the relative proportion between the two ingredients, and from the manner in which the union is brought about. Thus, malleable iron, such as is formed into bars and wire, contains a very little carbon; steel contains rather more; cast-iron contains a variable quantity, according to the purposes to which it is to be applied, but always a greater proportion than steel and a less proportion than plumbago (or, as it is misnamed, "black-lead"). A mere difference in the relative proportion of the two ingredients, therefore, will not suffice to explain the difference between iron and steel. Steel, in its composition, occupies a middle place between malleable iron and cast-iron; but its qualities are very different from either, and these qualities appear to be due to the manner in which the two ingredients combine. Sometimes the combination presents a granulated texture, sometimes fibrous, sometimes crystalline, sometimes smooth and glittering, at other times rough and dull. Even scientific and practical men best qualified to master the subject, have not yet shown why and how these changes take place; and it will therefore be out of place for us here to attempt any minute explanation. It will suffice for the present object to state the matter thus—that all our steel is made from bar-iron, which iron had been previously made from the ore by the processes of smelting, forging, &c., as described in the last chapter; that the change from iron to steel is brought about by a long and careful series of processes, in the course of which carbon is absorbed by the iron, and that the steel so produced derives different qualities according to the subsequent processes which it undergoes.

The amount of steel annually manufactured in England is twenty-five thousand tons; one-half of the iron consumed in this manufacture is imported from Sweden and other parts of the Continent, while the remainder is obtained from our own mines. It may appear strange, and indeed has about it something very remarkable, that notwithstanding the immensity of our iron manufacture, all our finest steel is made from iron brought from abroad; and that this iron (for the finest steel) is procured from one single district, brought to one single English port, and consigned to the hands of one single firm. There appears reason to believe that this will not continue to be the case to so great an extent as it has been; but it is at present sufficiently near the truth to require at the outset a little explanation.

There is among the iron-mines of Sweden, one which yields iron better fitted for making steel than any other yet discovered, at least in an available form; and the English steel-makers have found this iron so valuable for their finest purposes, that they have been content to give a very high price for it, rather than employ English iron. The iron-mines of Sweden, taken collectively, are governed in a peculiar manner, which imparts the character of a very strict monopoly to the sale of Swedish iron in England. Each forge has its particular mark stamped on the bars of iron it produces, which is correctly copied into a register, with the name of the place where the establishment is situated—the names of the proprietors of the work—the commissioner or agent for the sale of iron—the assortment each makes, and to what country it is generally shipped—the quantity annually made by each work—the quantity which each work delivers to the Government (which is about one per cent. on the quantity of the iron produced)—the determination of the quality of the iron of each work—the place and province in which the works are situated—the place from whence the iron is generally shipped—and how many forge-hammers there are at each work.

Among the mines thus regulated is that of Dannemora, which supplies England with the best iron for making steel. It is situated about thirty miles from Upsala, and has now been worked for nearly four centuries without failing in the abundance of its rich supply. The mine first belonged to the King of Sweden, then to the Archbishop of Upsala; but now it belongs to several private individuals, who work it separately on their own account. The ore differs in quality in different parts of the mine; some yielding 25 per cent. of cast-iron, and some as much as 75 per cent. The ore is blasted with gunpowder, and, after being broken in small pieces, is roasted. The smelting is effected in conical-shaped furnaces; the fuel employed being charcoal. The cast or "pig" iron obtained is as white as silver, completely crystallized, and very brittle; and to convert this into malleable iron, it is heated in a bed of charcoal, and hammered out into bars, which are found to have a fibrous texture and a very tough quality. "The quantity of iron which this mine yields every year," says Mr. Scrivenor (from whose interesting 'History of the Iron Trade' these details are chiefly taken), "amounts to about four thousand tons; the whole of it is sent to England, to the house of Messrs. Sykes of Hull, where it is known by the name of Oregrund iron, taking its name from the port at which it is shipped. The first or best marks are 'hoop-L,' which sells at £40 a ton, and OOCL, which sells at £39 a ton; while the best Russian mark, the CCND, seldom fetches a higher price than £20 a ton. The cause of the superiority of the Dannemora iron has never been explained. Some chemists ascribe it to the presence of manganese; Berzelius attributed it to the presence of the metal of silica; while others suppose it to arise from the nature of the process employed." So different, however, are the latest opinions on this subject, that one writer considers silex the chief obstacle to the formation of steel, and manganese he esteems to be useful only for removing the silicon. "All our energies," says Mr. Overmann, "are to be directed against silicon, or silex; because, if there is too much in the iron, it will degrade the steel. There never can be too little silex in the iron to make good steel of it." Silicon is necessary to the steel, but the less the better; 98 parts iron, $1\frac{1}{2}$ carbon, $\frac{1}{8}$ silicon, and $\frac{3}{8}$ sulphur, make good steel. The silicon adheres so tenaciously

to the iron, that it is difficult to reduce the amount to the proper proportion. 97 parts of iron, 2 of carbon, and 1 of silicon form brittle, hard cast-iron, not steel.

There is an allusion above to "marks," which may need a little explanation. Each kind of iron has a reputation of its own, great or small, as the case may be; and the more highly it is esteemed, the more earnest are the makers in wishing that no other should be mistaken for it. Hence has arisen the custom of stamping some symbol on the end of each bar, by which the quality of the metal shall be known. Thus, CCND is the symbol of the Russian iron brought from the mines of Prince Demidoff, a quality highly valued for many purposes; "hoop-L" (that is, a letter L encompassed by a hoop) is the still more celebrated and valued Swedish Oregrund iron; while others are designated the "double bullet," the "gridiron," the "steinbuck," the "C and Crown," &c., according to the symbol stamped upon the bars. Besides the Dannemora iron, the remainder of the foreign iron used in this country is common Swedish, Norwegian, Russian, German, and Madras iron.

We have found, then, that English steel is to a great degree made from foreign iron, brought to the port of Hull; and we have to trace it from thence. Some small portion goes to London, some to Newcastle, some to Birmingham; but all these are fragmentary and trifling compared with what goes to Sheffield. Here we find the centre of the steel trade, ramifying into a multiplicity of branches almost endless. Sheffield is as completely the metropolis of steel, as Manchester is of cotton or Leeds of woollens. There is not a corner of the world where a British ship is allowed to enter, but could exhibit some specimens or other of Sheffield steel goods. The rivers of Sheffield, if they could speak, would tell how busily they are employed in setting in motion the machinery for bringing steel to some one or other of its numerous forms; while the thoughts of the inhabitants, the names of many of the streets, the arrangement of the buildings, and the corporate usages of the town—all point to steel as being indeed a precious metal to Sheffield.

There are in this busy town several large establishments called Steel-Works, where the bar-iron is converted into steel, and brought to a form fitted for the numerous workers in that metal. Some of these, according to the technical phraseology of the town, are "tilts," some are "mills," some are "converting-works," while a few comprise all the varieties within themselves. To understand this, it will be necessary to remark that manufactures are extremely subdivided at Sheffield, as at Birmingham; skill in one branch or sub-branch of manufacture having been deemed a sufficient reason for confining attention thereto, to the exclusion of others.

Some works or manufacturers are wholly occupied in *converting*, or making the crudest form of steel; others in *tilting*, or giving a further development to the steel; others in *casting*, or giving to steel a still higher quality by pouring it into ingots or moulds in a liquid state; and others in *milling* or *rolling*, whereby the steel is brought into the form either of bars or of sheets; while in some few cases the converting, the tilting, the casting, and the rolling, are all carried on in one establishment. The whole neighbourhood of Sheffield is singularly favoured as to facilities for manufactures. The town is in a hollow, nearly surrounded by hills; and several small rivers flow between these hills into the hollow, thus affording moving power for a large number of water-wheels.

The "converting-furnaces" are the scene of the first stage in steel-making. The object in view is to saturate iron bars with carbon to such an extent as to change their quality from iron to steel. The bars so saturated are of various widths, and are partly Swedish and partly English, according to the purposes to which the steel is to be applied. These bars, when adjusted to convenient lengths, are packed or piled up in the converting-furnaces in a singular manner. Each converting-furnace, viewed outwardly, has somewhat the shape of a glass-house, being a sort of conical covering to an oven of very large size. The oven contains two oblong receptacles or boxes, each measuring nearly twenty feet in length, about a yard deep, and the same in width. They are so placed with respect to each other, that a strong body of flame may play around both of them, and raise to a high heat whatever may be placed in them.

Fig. 1 is a section vertically through the chimney of a "converting-furnace," representing the cementation-boxes, fire-grate, and the arch over the boxes; fig. 2 is a horizontal section of the boxes and flues. The grate, A, divides the interior of

Fig. 1.

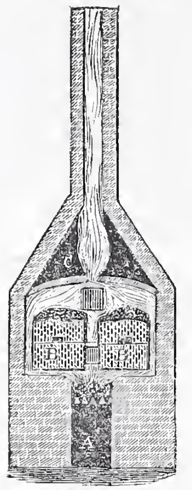
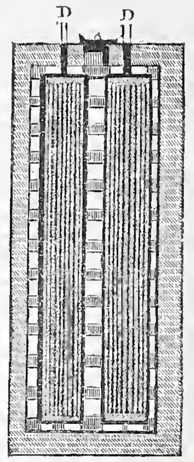


Fig. 2.



the furnace into two equal parts, each containing a cementation-box. The fire passes entirely round the boxes, B B, and finally escapes at C, where a succession of draft holes is left in the arch, so arranged as to admit of being either partially or entirely shut, to regulate the heat. At one of the smaller ends of the furnace are two small orifices, D D, for drawing out the proof-bars.

The boxes are made of sandstone slabs, the joints of which rest upon, and are covered by, the tongues which form the flues; the slabs are cemented together by fire-clay. They are charged in the following manner:—On the bottom of each box is placed a layer of coarsely-powdered charcoal or *cement*; then a layer of iron bars, placed side by side, as many as the width will admit; then another layer of charcoal; then a layer of iron bars; and so on till the trough is filled, at which time it contains more than thirty alternations of iron and charcoal. The surface is covered with a clayey substance called *wheelswarf*, derived from the abrasion or wear of the numerous grindstones used at Sheffield, made into a kind of putty. The carbonaceous matter, or cement, in which the bars are imbedded, consists of ground charcoal, sometimes mixed with soot, or of soot only. This charcoal powder is intimately mixed with one-eighth or one-tenth of its weight of wood-ashes, and a little common salt. Good steel is made without ashes or salt, by using simply charcoal powder; but the general practice is to use a cement of the kind above described. A fire is kindled with Sheffield coal (which is found to be excellently adapted for this purpose), and kept up fiercely for many days. During this time the iron is in a red-hot or perhaps a white-hot state; the charcoal is also highly heated; and the iron seems gradually to absorb a portion of charcoal into the very heart of the bar. The coating of wheelswarf prevents the charcoal from burning away, and thereby leaves it in a condition to act upon the iron. One or two bars are so placed in the trough, that they can be drawn out without disturbing the others; and from the inspection of these proof-bars, the workman tests the progress of the operation. The proof-bars are somewhat longer than the others. An experienced steel-maker uses but one, though some persons think it necessary to have two or more. If a trial-rod has been once drawn, it cannot be returned to the box; it is then broken, and from its appearance on fracture the quality of the steel is judged. Steel for coach-springs requires less of this action, or a "lower degree of conversion," and is therefore exposed to a lower heat than any other; steel for numerous common articles of manufacture requires a higher conversion; steel which is afterwards to be "sheared" or hammered for

knife-blades and other purposes, still higher; steel for files requires a yet higher degree of conversion; and steel which is afterwards to be cast in a fluid state requires the highest of all. The business of the steel-converter, therefore, is one of some nicety, demanding the exercise of care and judgment. The fire requires to be very gradually raised. For the first twenty-four hours the heat is merely sufficient to expel the moisture in the boxes, cement, and cover. A rapid heat would injure the stone slabs or bricks of which the chests are made. The fire is gradually increased so as to raise the heat a little every day; and at the end of six days, if it is designed to make spring-steel, the bars are ready to be drawn. Shear-steel requires eight days, and cast-steel from ten to twelve days, to be sufficiently cemented or carbonized. Two days, and often a much longer time, are required to cool the furnace; after which the workmen enter it, and discharge the steel bars. Twelve tons of steel are generally made in a double furnace.

We have said that it is one of the peculiarities of Sheffield to subdivide the several stages in manufacture, and to appropriate each stage to one set of manufacturers. This system may be illustrated by the case now under notice. There are many manufacturers in Sheffield who keep converting-furnaces only; they receive the iron in bars, pass these bars through the process of conversion, and then their department is ended. To obtain, therefore, an idea of the general character of Sheffield industry, it will be necessary to bear in mind that the operations of the converting-furnace are considered to be one branch of manufacture, distinct from and not necessarily associated with others.

The bars of iron when removed from the converting-furnace are in that state which procures for them the name of *blister-steel*, being entirely covered with blisters. They have absorbed only about one per cent. of carbon, gaining about a half to three-fourths of one per cent. in weight, yet their quality is greatly changed. The steel is very irregular in the different layers of the box, as also in each bar. The fracture of a bar is very crystalline, its colour a bright silvery white, and the tables of the crystals are lustrous, like brilliants. The central crystals are always smaller than those near the surface of the bar.

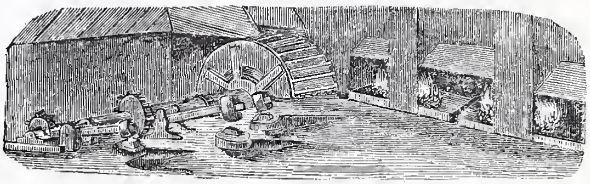
The steel, in this form, is not regarded as a material for manufactures, except for coarse goods; it is carried to a further stage before it has the necessary compactness and completeness for use in finer work, since the blisters, even if no other defects existed, would unfit it for all but coarse purposes. It obtains the name of *common steel*, when, after being again heated, it is hammered with a very ponderous hammer, whereby a tougher quality is imparted to it. The most customary process to which it is next subjected is *shearing*—a name worthy to be classed among those which illustrate the odd nomenclature of manufactures. When we see "shear steel" stamped on table-knives, we may not inaptly imagine that it is steel which has been cut with a pair of shears; but the connection is more remote. This steel, soon after its introduction, being found suitable for making shears, it obtained the name of *shear-steel;* and by another step in the same road, the process came at length to be called *shearing*—a name about as consistent as it would be to apply the term *shoeing* to the process of tanning a calf-skin, on the ground that it makes leather fit for shoes.

The process of shearing steel is somewhat analogous to the welding of iron. It consists in heating several pieces, and hammering them one upon another, until all form one mass, greatly more dense, compact, and tough than the blister-steel from which it was made. This department of the manufacture introduces us to some new features of Sheffield arrangement. A *tilt*, or *tilt-house*, or *shear-house*, is a building constructed with special reference to strength and resistance of vibration. Within this building are furnaces for bringing the pieces of blister-steel to a proper heat for welding or shearing, and hammers of enormous size and remarkable construction. Some of these hammers are shear-hammers, employed in the operation now under notice; while the others are tilt-hammers, for a process which will be noticed further on. The heaviest hammer—the shear-hammer—varies in weight from 200 lbs. to 400 lbs.

The hammers are driven by a shaft or drum, worked by a steam-engine, or by a small water-wheel, upon whose prolonged axis are one or more iron rings, which contain the wipers, or cams. In the periphery of the cam-ring, or wiper-wheel, there are from twelve to eighteen cams, which strike the tail of the hammer in rapid succession, by which the hammer-head is raised and suffered to fall on the steel. To increase the effect of the hammer, a spring is placed under its tail, so as to work the hammer partly by weight and partly by recoil. Large tilts make two hundred, smaller ones four hundred, strokes per minute. The majority of the hammer frames in Sheffield are of wood, which in fact is the most suitable material for tilts. In some establishments, more than one hammer is on one wheel shaft. The anvils are placed upon a stone foundation, and these stones upon a grate of wood-piles. The surface of the anvils is almost level with the floor of the tilt-house, and the workman sits down in a fosse, or pit, with his face towards the hammer. The smaller rods are tilted sitting, the larger ones standing. Each tilter has two boys in attendance, to furnish him with hot rods, and take away those which are sufficiently hammered. The rods are heated to a higher or lower degree, but, after the welding is done, not higher than a cherry-red. Small rods of good steel, which very soon cool after being brought upon the anvil, speedily become red again under the rapid blows of the hammer.

Tilting is a very important process in the manufacture of steel, and none but very skilful and industrious men will make good hands at the tilt. In fig. 3, as will be seen at a

Fig. 3.



glance, a tilt-house is represented. The faces of the hammer-head, as well as the anvil, are of the best cast-steel, well hardened and polished. Each hammer has a blast-pipe conducted to it, which ends in a nozzle, from which a stream of air is constantly blowing upon the anvil, to keep it free from dust and scales. This cleanliness is necessary to impart a good polish to the steel bars.

The bars of blister-steel are broken up into pieces about a foot long. These are heated in a furnace or forge, and when at a white heat, they are brought under the operation of the large tilt-hammer, by which they are beaten out to thirty inches in length, and now constitute common steel. To change these pieces into shear-steel, half a dozen of them are put one upon another in a pile, and fixed firmly at one end in a groove or long handle. The group thus connected is placed in a furnace to "soak," according to a technical phrase, that is, to be partially heated, preparatory to a more intense heating. The group is taken out of this first furnace, and transferred to another, where a fierce fire brings it to a white heat. The workman attends carefully to the state of the steel while in the furnace, as great nicety is required in the degree and equalization of the heat attained. When sufficiently heated, the group (still held by the handle) is taken out of the fire, and placed under the largest or shear-hammer, where it is beaten on all four sides, until all the pieces become thoroughly amalgamated or welded one to another, and the result appears in the form of a bar of steel two or three inches square. In some cases, the bar is cut in two, heated again, and again welded, whereby the process is carried still further. According to the degree to which it is welded or sheared, the steel is called "double-shear," "single-shear," or "half-shear." During the heating in the furnace, preparatory to the hammering, the group of pieces requires a degree of attention, whereby the workman is exposed to a very intense heat.

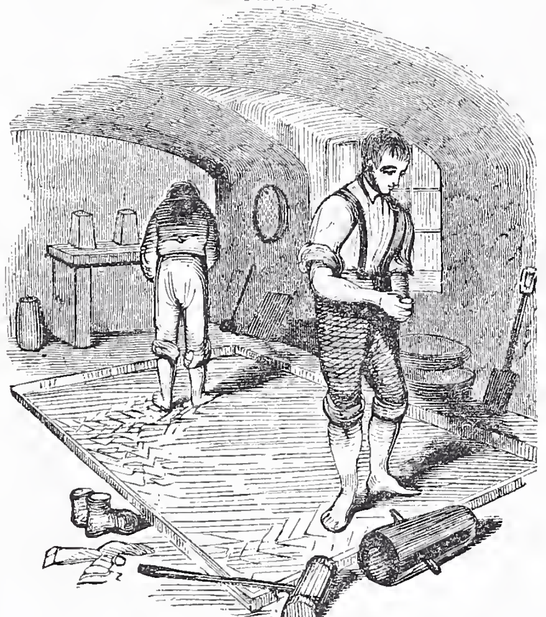
The shear-steel made by this process, when closely examined, is found to have lost all the flaws and blisters which dis-

tinguished it as blister-steel, to have acquired a uniformity of character throughout, and to be greatly more malleable and tenacious than it was before. It is, therefore, a superior steel for cutlery, is susceptible of a very fine polish, and unites a close texture with great tenacity.

There is, however, yet to be noticed a kind of steel more important than either of those hitherto described, and one to which the beauty of modern steel goods is in great part indebted: we allude to *cast-steel.* As the heat employed in melting steel is the greatest which the manufacturing arts of any country exhibit, the furnaces, the crucibles, and all the apparatus employed, must be so formed as to endure this heat; and we must, therefore, notice these appliances before we can understand the process itself.

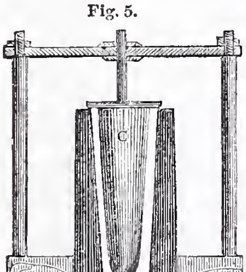
The crucibles or melting-pots are rather less than two feet in height, and have a somewhat sugar-loaf shape. They are made of Stourbridge clay, wrought to the greatest possible degree of uniformity and smoothness. To give this uniformity, the clay, after being mixed with water and well worked up, is spread out in a thin layer on the floor of a room under the casting-house. Two men, with naked feet, tread or trample on the

Fig. 4.



clay uninterruptedly for five or six hours—walking, or jumping, or dancing, or shuffling (for it is hard to know which to call it), over and over again, from side to side, and from end to end, until every particle of clay has been trodden repeatedly. It might seem strange why some kind of mill should not be employed in this operation; but those who are most likely to understand the matter, state, that no other method equals this for bringing the clay to a perfect uniformity of substance, and expelling all air-bubbles.

Fig. 5.

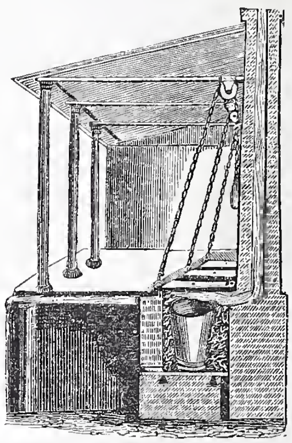


When the clay is prepared, it is made into crucibles weighing about twenty-six pounds each, by fashioning it in a mould having a core to give the internal form. This mould, which is of cast-iron, is represented in fig. 5. A is a solid block of wood, in which the outer part of the iron mould, B, closely fits, but still so loose as to be easily lifted out of its place. This iron mould is well bored out on the turning-lathe, and polished. The core of the mould, C, is also of cast-iron, well turned. It has two guide-pins, one above and one below. In the space between the core of the mould and the case, a lump of clay is laid on the bottom, just sufficient to fill the space and make a crucible. When the proper size of a lump has been found by experiment, it is weighed, and its weight made the standard for future operations, thus securing uniformity in the crucibles. A dried and baked Sheffield crucible weighs from twenty-five to thirty pounds, and will contain forty pounds of broken steel.

The crucibles, as they are made, are placed in a vault where both air and warmth can come to them; and when dried by this means, they are placed, on the night before they are to be used, on an annealing grate, where they are covered with cinders, and allowed to remain till the next day. These operations of crucible-making are continued uninterruptedly; for, notwithstanding the care and trouble bestowed, each crucible will last only three heats, or one day.

The casting-house, which has a great resemblance to a brass-foundry, is paved with stone, with brick, or with earth, and has a dozen or more furnaces in one or two ranges. These furnaces are very different from others which we have had to mention; for they exhibit to the eye nothing but a hole in the floor about eighteen inches square, as shown in fig. 6. So long as they are covered by iron covers or lids, there is nothing particular to be seen; but when one of these lids is removed, a fearfully intense heat is shot upwards from beneath. Each hole is the mouth of a furnace; and each furnace is a cell measuring about four feet deep by eighteen inches square, being merely large enough to contain two crucibles with the requisite quantity of fuel. There is a grate beneath, through which a powerful draught ascends to the fuel; and there is a flue at one end to carry off the smoke and heated gases. Neither bellows nor blast-engine is used the intense heat being wholly excited and maintained by the judicious admission of air from a vaulted chamber beneath. The crucibles are made and dried in these vaults. The pit of the air-furnace is a square cavity; if intended but for one crucible, it is twelve inches square—if for two, it is twelve by eighteen inches. The crucibles being six inches wide at the top, there is a space of three inches all around. The depth of the fire-pit, from the top of the grate-bars to the floor, is twenty-four or twenty-six inches. The flue leading from the furnace to the stack is three and a half by six inches in a single, and three and a half by nine inches in a double furnace. The crucible stands on a sole-piece of two or three inches high; this may be either a piece of fire-brick, a lump of fire-clay, or the bottom of an old crucible. The walls of these small furnaces are exposed to such a destructive temperature, that the selection of the material with which they are lined becomes a matter of much importance. This material obtains the name of *ganister:* it is a kind of stone found near Sheffield, and is used, in the first instance, as road-metal; after which, when ground to dust by wheels and horses' feet, it is collected and made into a plaster or lining for the furnaces.

Fig. 6.



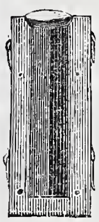
Let us now see what passes in one of these cast-houses. Each crucibleful of metal requires about four hours to effect its perfect fusion; and there are three successive meltings in twelve hours. Each furnace is supplied with coke to a certain height; and the two pots or crucibles are adjusted within it, side by side. More coke is then thrown in, until both pots are entirely surrounded by it. Here they are left to be acted upon by the fire, until they are brought to a dazzling white heat. The cover of the furnace is opened, and a long funnel made of sheet-iron is let down into each pot, having its open end at a

convenient height above. The steel, broken up into small fragments, and amounting to thirty or forty pounds for each pot, is thrown into the funnel, and allowed to fall down into the pot. The funnel is then removed, a cover made of pot-clay, which fits the crucible, is now laid upon it, fresh coke given to the fire, and the heat gradually raised to the melting point of steel. This operation requires from one to two hours; and in the meantime the furnace is frequently opened, and fresh coke charged, so that the fuel may be higher than the top of the crucible. Before the steel is melted, the lid is removed, and a little bottle-glass, or pounded blast-furnace slag, is thrown in. This will form a vitreous cover on the surface of the melted steel, and exclude the access and influence of atmospheric air, in case the cover of the crucible is not sufficiently tight for that purpose. A great deal of fresh air draws in at the furnace door, even if it fits well.

After the fusion of the steel, the crucible is still kept standing in the fire, to fuse it perfectly, and give time for the interchange of atoms in the fluid mass. As the melting process is chiefly for the purpose of making a uniform grain, those portions of the steel which have more carbon than others, have to dispose of a portion of it, and thus equalize the whole mass.

As the time approaches for the casting, the men make preparations which sufficiently indicate the sort of "Fire-King" ordeal to which they are about to be exposed. They cover their legs and body with coarse sacking or leather, saturated with water from a trough at hand, and prepare to fill the ingot-moulds with the melted steel. Fig. 7 is a section of one of these moulds. They are formed of metal, so shaped as to give oblong bars or ingots weighing from thirty-six pounds to two hundred pounds each, according to circumstances. The moulds are perhaps three times the weight of the cast, and about three feet long. Each mould is divided into two halves, which halves are bound closely together when the casting is about to take place. The mould is first coated on the inside with a kind of oily composition, closed up tightly, and placed vertically in a hole in the stone floor of the cast-house, with the upper end, which is of a bell-mouthed shape, open. One of the men draws off the lid of a furnace, and the white-hot coke is removed from about the pot which is about to be emptied. A man then takes a long instrument, acting like pincers or tongs, hovers over the furnace in a manner which is almost fearful for a spectator to witness, puts the tongs down into the furnace, grasps one of the pots firmly, and draws it up; having during this time his face directly over a furnace so intensely heated, as to convert steel into a liquid, and drawing up, in this hazardous position, a white-hot crucible weighing with its contents sixty pounds. He rests the glowing mass with its lower end on the floor; another man strikes off some of the adhering slag with a long iron bar; a third man grasps the crucible with an instrument held horizontally; the first man loosens his hold, and with his tongs takes off the cover of the crucible; the third man lifts up the mass (no trifling weight when held horizontally at the end of a bar), goes to the ingot-mould, and pours the liquid steel into it; while a fourth man, standing before him, clears the liquid stream from any impurities as it flows, by means of a long rod. Thus all four have their prescribed office; and no description can give an adequate idea of the scene which is presented. The terrible yawning mouth over which the first man hovers, the glowing mass which he draws forth, the intense whiteness of the liquid steel as it flows into the mould, the profusion of delicate greenish sparks which shoot forth during the pouring—all form a spectacle which, when once seen, will not be soon forgotten.

Fig. 7.



The part of this operation which exposes the workman to the greatest heat, is that of drawing the pot from the furnace; but the part requiring most skill is that of 'teeming,' or pouring into the mould, since it is necessary that the liquid stream should fall directly down the centre of the mould, without striking against the sides more than can be avoided. The eyes of the men are weakened by the intense glare to which they are exposed, but it does not appear that the general health suffers in any marked degree; yet a stranger may well marvel how any human frame could bear such a trial for years together.

Immediately after each pot is emptied, it is returned again to the furnace, again brought to a white heat, again filled with pieces of steel, and again exposed to four hours' heating. After this has occurred three times, or one entire day, the melting-pot has rendered its services, and is then cast aside to be replaced by another. With regard to the steel thus melted, certain important changes have taken place within the last few years. It has often been conjectured that the Swedish iron derives some of its valuable properties from the presence of a small quantity of manganese; and within the last few years manganese has been introduced as a material to be added to the bar-steel in the melting-pot, in order to impart to the cast-steel certain valuable qualities which it did not possess before this improvement was introduced—such as a facility for being worked up into certain articles of cutlery.

If the cast-steel is for the purpose of making saws, the ingots are rather flat, so as to be conveniently rolled into sheets at the rolling-mill; but if for other purposes, they are generally about as thick as they are wide. The rolling of steel into sheets or into bars is so precisely analogous to that observable in the iron manufacture, that the same description suffices for both. The rolls are very ponderous, weighing as much as five hundred pounds each; and when they are about to be used, the steel, whether 'shear' or 'cast,' is heated in an adjoining furnace, and passed repeatedly between the rolls while yet red-hot, by which it assumes the form either of bars of any required shape or of sheets.

The *tilting* of steel is another curious process, the object of which is to close the pores of the steel, and to render it as dense and compact as possible. All steel for the best articles is tilted before being applied to use, whether it be 'shear' or 'cast;' and the tilting is thus effected:—There are two swings or suspended cradles in the tilt-house, one near each tilt-hammer. In these swings the men sit while holding the bars of steel to be tilted; since they can move their bodies to and fro (to bring every part of each bar under the operation of the hammer) more easily when they thus sit, paddling along with their feet, than if they stood or walked. The bars of steel are heated to a certain temperature in an adjoining furnace, and are then brought under the action of the tilt-hammer, where a deafening clatter is kept up for some minutes, accompanied by a vibration all around, which would shake to pieces any but a building of great strength.

It is one of the peculiarities of Sheffield that tilting is a trade by itself. In a map of the town we may see marked Mr. So-and-so's '*Tilt*;' for with the usual brevity of technical language, the whole building, with its hammers and furnaces, is called a tilt. These tilts are mostly situated on the banks of some one or other of the rivers which flow through Sheffield; and it is impossible to mistake them when once in their neighbourhood. There is one, for instance, close to the Lady Bridge, where from morning till night there is an incessant thumping, which shakes the very roadway itself. These tilters, or proprietors of tilt-works, receive steel in the form of bars from any parties, and pass it under the tilt-hammers; after which their occupation is ended.

Cast-steel is much harder under the tilt than any other steel, and, what makes it still worse, it will bear but a low degree of cherry-red heat before it becomes brittle, and falls to pieces under the hammer. Nor will it bear piling and welding like other steel, but in this respect very closely resembles cast-iron. Another characteristic of cast-steel is, that it is always more highly carburetted than other varieties, in order to make it fusible. Steel which contains but little carbon, requires too high a heat to be melted to advantage in crucibles.

Having thus traced the conversion of iron into steel through all the processes commonly practised in this country—producing in succession blistered-steel, common-steel, shear-steel, and cast-steel—we shall conclude the present chapter with some account of other varieties of steel which are known by distinguishing names, though all of them are more or less modifications of those we have already described, or alloys of steel with other metals.

Silver-steel belongs to the latter class. Indeed it is the only alloy of steel that ever came into practical use. This was composed of steel and one five-hundredth part of silver, and was for a time known as silver-steel of superior quality. It has probably fallen into disuse, as we do not hear of it at the present day. Other alloys than those of the precious metals deteriorate the value of steel, and there is some doubt as to the beneficial effect of silver. On the whole, we may conclude that there is no advantage in forming any alloy of steel; it increases the expense, without any corresponding improvement.

German-steel derives its name, not from being of a peculiar quality, though that is the case, but from the manner in which it is manufactured. It is always made of pig or plate-iron, in forges where charcoal is used for fuel. Natural steel may be made of grey pig-iron or of white plate-iron; the latter is the cheapest method, and produces the best steel. The German method of making steel is to use cast-iron derived from the smelting of carbonate of iron, or sparry ore. The art among the Germans is highly cultivated, and is practised in a variety of forms, with a view to vary the quality and quantity. German-steel is frequently found to be very hard and tenacious, equal to good cast-steel; but the quality of German-steel is so irregular, that no dependence can be placed upon it. We frequently find very hard and tenacious steel, and very soft and brittle steel, in the same bar of but a few feet long. We often also find fibrous iron and good steel in the same fracture of a bar. The hardest iron or steel known is the white cast-iron or steel-iron of Germany, of which German-steel is made. It is, however, so brittle when hardened, that it will not serve for any practical purpose. Some kinds of wrought-iron may also be hardened, but the metal is never sufficiently tenacious to assume a fine edge; for the edges formed of it are so brittle as to break when exposed to slight pressure.

There are some kinds of steel which have but an historic interest for us—such as the Asiatic Damascus steel and Indian wootz—which, though not found in our market as merchandise, deserve a brief notice.

The most ancient steel, historically known, appears to be the Indian cast-steel, or "wootz." The ancient Egyptians imported steel from Asia and Bombay *via* Persia—the great high roads of the Indian trade. At the time of the invasion of India by Alexander the Great, when the Greeks made their weapons of bronze, wootz was manufactured in India. English travellers in modern times have been very inquisitive as to the mode of manufacturing wootz among the Asiatics, and also as to the material from which it is made. They have succeeded very well; but the operation is of such a nature that we cannot derive much practical benefit from it.

Wootz is made of magnetic iron ore. This ore, which is naturally mixed with quartz, and which appears to be very impure—for nearly half of it is quartz—is finely pulverized, and the impurities winnowed away. The fine ore is then moistened with water and formed into cakes, to prevent its running down through the hot coal in the smelting furnace. The furnace is of the form of one of our cupolas, about four feet high, and two feet wide at the bottom by one at the top. It is charged with charcoal and thoroughly heated. The breast, or front opening, which is about a foot wide, is then closed and dried, and a certain quantity of ore is laid upon the hot coal, at the top of the furnace, which is kept filled with fresh coal, and the blast applied. This is made by two goat-skins, which, being worked alternately by hand, make a uniform blast. The nozzles are of bamboo sticks, fastened to the neck of the skin; the tail, and a similar bamboo, forming the valve, which is shut and opened by hand. The tuyere is made of clay.

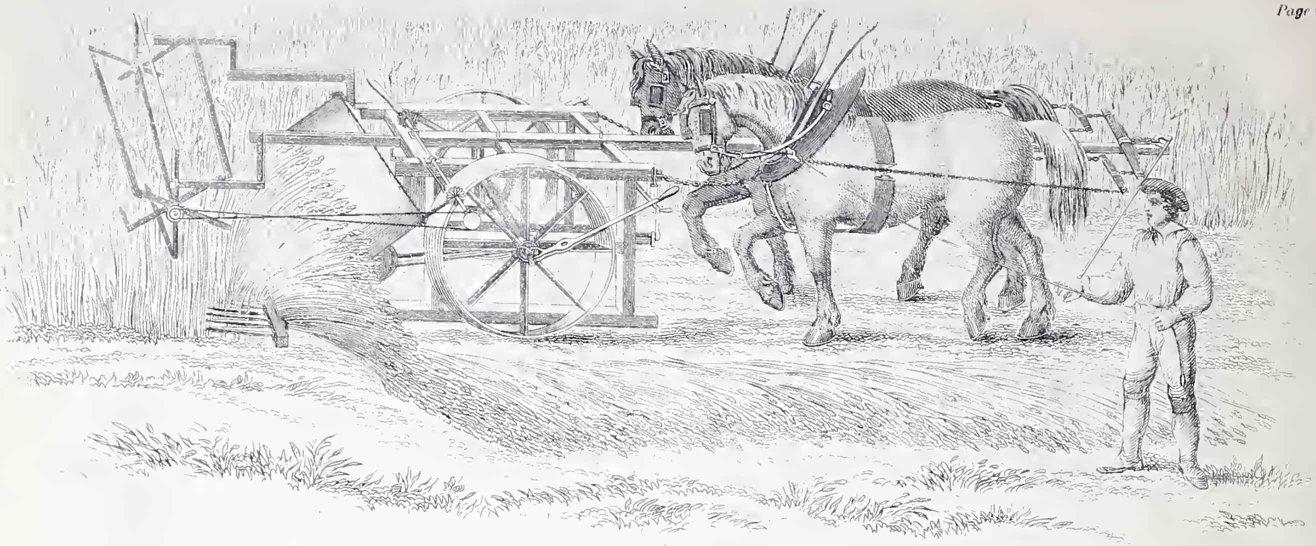
From three to four hours generally finishes the blast. The breast-wall is then broken open, and the iron from the interior of the furnace removed. The metal, then in the form of a cake, is beaten down with wooden mallets, and cut so as to show the interior, but not broken; in which form it is ready for the market. The ore yields about fifteen per cent. of iron. It is from the iron thus obtained that the wootz, or Indian steel, is made. This iron is cut into small pieces, and charged with about ten per cent. of dry wood in crucibles. The crucibles are made of fire-clay, mixed with the charred husks of rice. One pound of iron is generally a charge for a crucible: it is covered with a couple of green leaves, and a layer of fire-clay rammed on closely. This crucible, when charged, is gently dried to expel all the water and hydrogen. From twenty to twenty-four of such crucibles are then built, in the form of an arch, into a small furnace, and covered by charcoal all around, when fire is applied, and this at last urged by blast. Two or two and a half hours of blast generally finish the work; the crucibles are then removed from the fire, and allowed to cool. When cold, the crucibles are broken up, and the steel is found in the bottom in the form of a cake. Good cakes show a radial crystallization on the upper surface, and are free from holes and blisters. An imperfect fusion shows a rough surface, or honeycomb appearance, with lumps of malleable iron. In this form the steel is brought into market, and corrected, in remelting the cakes, by fusing many together, and running them into ingots like common cast-steel. It is said that wootz which has been remelted in this way, is superior for the manufacture of cutlery to any cast-steel.

In this process of converting iron ore, first into iron, and then into steel, we find all the elements of our present mode of doing the same business. The blast-furnace of the Asiatics is, on a small scale, our present blast-furnace; though, owing to their imperfect operation, the ore which yields them but fifteen per cent. of iron, would, in our hands, yield at least sixty or seventy per cent. Instead of using, as they probably do, twenty tons of fuel, we use but two tons for the same quantity of iron. The Asiatic mode of converting iron into steel is the mode we follow at the present day; the only difference being that we divide the operation into cementing and melting, while they perform both in the same heat.

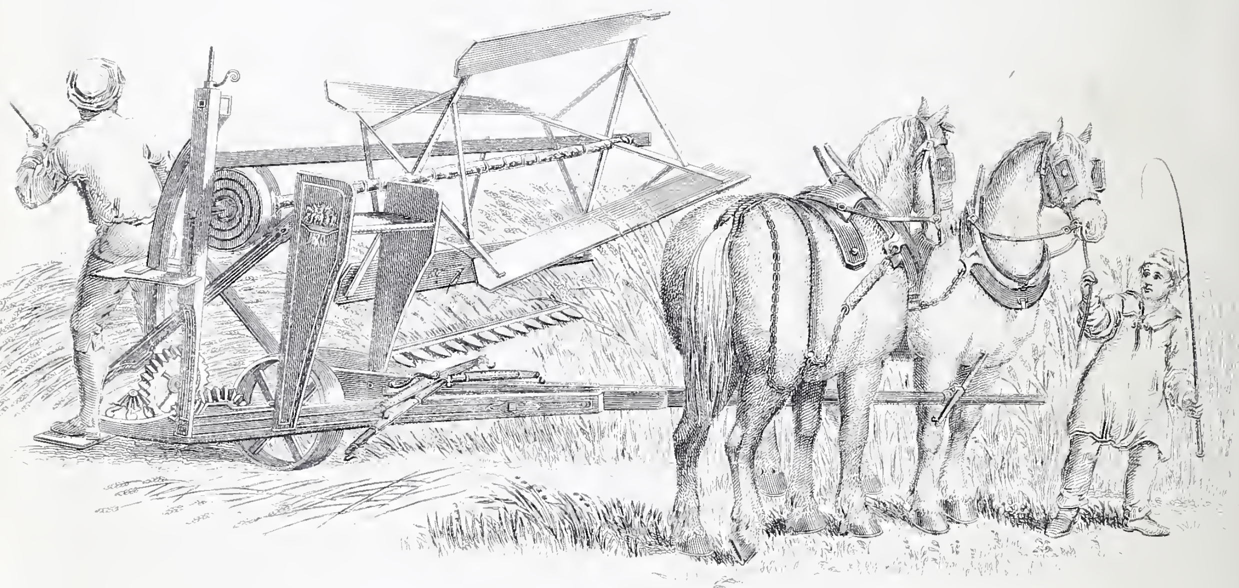
Damascus steel, from which the celebrated Damascus blades are made, is the term applied to a kind of steel which shows a variegated watery appearance on the polished surface. It is originally from Asia, and the scimitars or swords chiefly from Damascus, where the art of manufacturing blades appears to be best understood. The excellent quality of this cutlery, particularly scimitars, has long been proverbial; no other steel has been found to equal it in tenacity and hardness. The process by which this steel is worked is not known; it is a secret faithfully preserved among those who are engaged in the manufacture. European artisans and scientific men have endeavoured to imitate the Asiatic damask, but with ill success; the form and appearance of the steel has been imitated, but its quality has never been equalled. French manufacturers particularly have wasted a great deal of time and means in such attempts. The probable cause of the superior quality of this steel is in the raw material, the ore; and it may in some measure be attributable to the skill of the artisan who manufactures the blades. It has been ascertained, that the ingots of wootz, of which the oriental Damascus is made, come from Golconda; and it is therefore probable that it is manufactured in the same manner as the Indian wootz before described. This supposition is strengthened by the great value of the blades, and the peculiarities of the wootz.

Alexander Burnes, in his journey to Cabool, tells us that a scimitar was shown him in that city which was valued at five thousand rupees, and two others at fifteen hundred each. The first was forged in Ispahan, in the time of Abbas the Great. The peculiar value of this weapon consisted in its uniform damask; the "water" could be traced upon it, like a skein of silk, the entire length of the blade. Had this "water" been interrupted by a curve or cross, the blade would have been of little value. One of the cheaper weapons was also of Persian make; its water did not run straight, parallel with the blade, but was waved like a watered silk fabric. It had belonged to Nadir Shah. The third scimitar was a Khorassan blade; there were neither straight nor waved lines in it, but it was mottled with black spots. All three blades were strongly curved, but the first more so than the others. They tinkled like a bell, and were said to improve by age.

Imitations of Damascus steel are made daily, and have been made for the last fifty years; and there is no doubt some good has resulted from these experiments. The real value of the



BELL'S REAPING MACHINE.



M'CORMICK'S AMERICAN REAPING MACHINE.

HUSSEY'S AMERICAN REAPING MACHINE.

imitations, however, is quite limited. Damask steel has been made and is made of such perfectly developed veins, by welding together bundles of small slips of steel and iron, or steel of different kinds, that all imaginable figures which can be delineated by hand have been imitated. The smooth water, the waved water, a torsion of the damask, and the spotted damask, have all been produced; names, letters, inscriptions, leaves, and flowers have been represented; but all these pretty things do not make Damascus blades of equal quality with those of Asiatic manufacture. It appears the Persians do not use so much skill in forging, but depend upon the elements. Recent experiments have shown that when blades are cooled slowly, as by swinging them in the air, a damask is produced on steel highly charged with carbon. This, however, is nothing new; for the next best blades to those of oriental manufacture—the blades of Solingen—have been hardened or tempered in that way for centuries. It is certainly the most perfect mode of hardening steel, where tenacity also is desirable.

It is said that one hundred parts of soft iron, and two parts of lamp-black, melted together, make a fine steel, of great strength. It is also said that equal parts of cast and wrought-iron turnings make a fine steel, of damask quality, which is superior for arms and edged tools. There is no doubt that, by such means as the foregoing, an imitation of the appearance of damask steel may be effected; but it will depend entirely on the quality of the steel, the iron, the cast-iron, the lamp-black, or the crucibles, whether the resemblance will extend to the *quality* of the steel. Impure materials will, under all circumstances, make bad steel; and if we have good pure iron, we can make good steel in a cheaper way than that proposed.

Some experiments have been made by melting together cast-iron, carbon, and alumina, so that the molten iron contained aluminum. A portion of this aluminous iron was melted together with blistered steel, and the result was a steel very much like the wootz; it showed damask very distinctly. Other manufacturers than those who made the experiments, however, assert that aluminum is no necessary part of Damascus steel.

The damask veins may be made to appear on the surface of polished steel by washing it with a thin solution of sulphuric or muriatic acid, which will dissolve the softer parts of the steel first, or those parts which contain least carbon; after which the steel is washed in fresh water, and oiled or waxed. We do not know whether or not the Orientals bring out their damask in a similar way, but are inclined to believe that they do not. In some parts of Europe—Spain, Portugal, and portions of Italy—steel is buried under ground, often for months together, to improve its quality. May not this be the manner in which the Orientals etch their blades?

But such conjectures are of little practical value. We shall describe in our next chapter the conversion of steel into cutlery.

AGRICULTURE.

CHAPTER X.

MANAGEMENT OF A FARM DURING AUTUMN.

HARVEST.

From time immemorial, harvest has been a joyful time, and if the labourers have in it to work very hard, the additional wages that they received more than compensated them for it. Owing to recent improvements, the old-fashioned mode of reaping the corn crop is almost at an end, and last year, perhaps, saw the last of it. These improvements are, first of all, the substitution of the scythe for the sickle, and now the probable superseding of the scythe by the reaping machine, one of the results of the Exhibition of Industry of All Nations. Still, as the new systems of reaping have not come into actual play, an account of the mode of cutting the crop by the scythe and the sickle is proper in the first place, and then we shall describe a few of the new reaping machines.

When the harvest is reaped by the sickle, the greater part of the labour is necessarily performed by other labourers than those that ordinarily work the farm. Of these, a portion come from the large towns, and are almost invariably bad workers, inasmuch as it is only the refuse of the town population who have no stated employment that so come; another portion is obtained from the Highlands; and the remainder, including the greater part, come from Ireland. That these poor people are thus enabled to take home with them what is to them a considerable sum of money, usually £2, and sometimes more, is true; but it may be doubted if this be not a positive injury to them, by inducing them to continue in their present mode of life, and work so hard for a few weeks, and be idle and half-starving the rest of the year.

All reapers receive so much money, their food and lodging, if liberty to all, to lie huddled together in a barn, each with a pair of small blankets, constitutes the last of these. The food generally consists of porridge, night and morning, bread and beer for dinner, and they usually have beer at other times. Upon Sundays, they have for dinner broth and potatoes. Their wages vary each season according to the demand and supply. The average is about two shillings to half-a-crown a-day.

The person who takes charge of the shearers' blankets (they have chaff beds, each bed being shared by two, and usually a pair of sheets), and also prepares the food, is the dairymaid, and the person who carries it to the field is the cattleman.

The steward personally superintends the reaping, remaining with the workers constantly, giving the word to start and the word to cease, and taking care that the work is properly executed. The hours vary in different farms, and sometimes are affected by the weather. It is usual to start at five o'clock in the morning, work until eight, then breakfast, and rest for an hour; then work again until one, dine and repose until two, and work again till about seven. There is commonly a rest for a little in the afternoon to drink some beer.

On an average of years, it is found that reaping an acre by the sickle costs ten shillings, and if it be let, as is sometimes done by gentlemen farmers, rarely by tenant farmers, the usual price charged by a contractor is twelve shillings.

A great many practical inconveniences attend this mode of reaping corn. In the first place, it is a slow mode; and it is of the greatest consequence, when the corn is ready for cutting and the weather is fine, to have it cut at once. Then it is a very expensive process. The reaping of the grain crop upon a farm of so small a size as 250 acres, managed upon the four-course system, would amount to more than sixty pounds—a heavy pull off the farmer's income. The poor people who come, too, though willing enough, are not skilled workpeople, and thus often both annoy the steward and damage the crop. Reaping likewise, by cutting the straw at some distance from the ground, sends less straw to the barnyard than any closer mode of cutting would do; and as we have seen that the farmer is sometimes stopped from soiling for want of straw, this becomes a serious objection. The Irish and Highlanders have strong

national antipathies, and are apt to settle their quarrels with a fight.

Accordingly, reaping the corn by means of the cradle scythe has become much more common than it was, and, until the introduction of the reaping machine, bid fair to become the universal plan. It requires fewer people, costs about half the price, and cuts the straw close. It is not attended with any disadvantage. Those that have been raised are mere prejudices. With regard to the comparative work done in a given time, and therefore the expense, we may extract the experiment of a very intelligent steward, Mr. Taylor. The same number of workers reaped in ten hours—

	Wheat.		Barley and Oats.
	A. R. P.		A. R. P.
By the scythe,....................	2 3 0	....	4 0 20
By the smooth sickle,........	1 1 18	....	2 2 10
By the toothed sickle,........	1 0 8	....	2 0 10

Another advantage of mowing corn is, that it is ready to stack in about half the time that sickle-cut corn is.

The writer of this may perhaps be allowed to state, as illustrative of the superiority of mowing, that upon his own very little farm, he let, the harvest before last, his corn to a number of workers at twelve shillings the acre. They appeared to work pretty hard, but their gains were not half-a-crown a day. Last harvest he determined to mow it, and to do this by means of the people constantly employed upon the farm. One of the two men he intended to wield the scythe, had the misfortune, a little before harvest, to break some of his ribs, and no substitute was got in his place, the whole being managed without him. The people received liberal wages, being themselves sent to a farmer's to hear what the harvesters were getting, and allowed to fix what they themselves considered fair. The cost per acre was only four and sixpence.

Harvest generally commences about the middle of August, and it is usually calculated that it will last about three weeks. Autumn-sown wheat is the corn first ready, and beans the last.

The reaping machine bids fair to supersede even mowing. A great variety of these machines have been invented, though none of them has yet been introduced into common practice. Boyce's, which was patented early in the present century, was the first reaping machine of considerable promise. It was mounted on a two-wheel carriage, with fixed wheels or revolving axle, communicating motion to a vertical spindle, which descended to the proper cutting distances from the ground, where it was armed with a number of scythes horizontally adjusted; but it had no provison for gathering the corn into parcels, or for depositing it in heaps. Plunckuet's reaping machine was similar in general construction to Boyce's, but, instead of the scythes, was armed with a notched, sharp-edged, circular steel-plate. Gladstone's machine resembled Plunckuet's, but was provided with an apparatus for gathering the corn into parcels. Salmon's and Ogle's were constructed on a different principle, but as they have likewise been laid aside, we think it unnecessary to describe them.

Engravings of three of the latest reaping machines, and which may be regarded as now contesting the palm for superiority, are given in the Plate. These will be understood from the figures, without descending to minute details of description.

Smith's reaping machine, the invention of the late Mr. Smith of Deanston, in Stirlingshire, was tried in 1811, but did not come prominently into notice till 1816, and underwent various improvements from the date of its first trial till about the year 1837. Its cutter is a continuous circular knife, revolving with considerable velocity, somewhat on the principle of Plunckuet's. It is pushed by two horses, and cuts a breadth of about four feet, but it is unwieldy from its great length—about 20 feet. Its gathering apparatus comprises a revolving rake, which lays the cut corn down at one side of its track.

M'Cormick and Hussey's American machines appeared at the Great Exhibition in 1851, as competitors for public approval. M'Cormick's machine is drawn by two horses (requiring the labour of four horses throughout the day); it is attended by a man or boy to drive the team, and a man to take the grain from it into gravels of suitable size for binding. Six to eight men are required to bind and shock the wheat. This reaper is stated to cut 1½ to 2 acres of wheat or other small grain per hour, and is constructed to cut as high or as low as required. One merit of the machine consists in the extreme simplicity of its cutting part—a straight saw vibrating rapidly right and left, and the teeth inclining alternately in each direction. When tried against Mr. Hussey's, at Tiptree Hall, and on other occasions, it showed so decided an advantage as to gain the Council medal. Mr Hussey's was found to become clogged in the heavy and thickly-sown grain of this country.

But Bell's reaping machine, invented by the Rev. Patrick Bell of Carmylie, in Forfarshire, was found, from trials made in Scotland in 1852, to work even better than M'Cormick's. This machine was put into operation in 1827, and received a premium of £50 from the Highland and Agricultural Society of Scotland, but, until the recent trials against its American competitor, remained in comparative obscurity. It cuts on the clipping principle, by means of a series of shears; and combines with this a gathering apparatus, which lays the cut corn on an endless web, and thereby deposits it on one side of the track. It is pushed by two horses, and cuts a breadth of five feet.

Having thus cursorily described the principal cutting machines, we now proceed with the subsequent harvest operations.

After the corn is either mown or reaped with a scythe, it is bound into sheaves, and a number of these placed upright and leaning against one another constitute a stook. The corn must remain in these stooks until it has become sufficiently dry, and if stacked before being so, it heats or ferments in the stacks. The length of time that it requires to stand varies according to the weather. If mown wheat, it is ready in four or five days, and barley or oats in eight or ten. It requires considerable skill on the part of the farmer or steward to decide when the corn is ready for leading.

When the corn is pronounced fit for stacking, it is led in carts to the stackyard, where the stacks are built by the steward, this being considered one of the nicest operations about a farm, and one in the well doing of which stewards pride themselves. When the whole is stacked, the stacks are thatched. When this is done, the harvest of the year is over.

POTATO HARVEST.

By October it will be time to lift the potatoes. They are known to be ready when the haulm decays. The best mode of lifting this crop is to take the coulter from the plough, and run it between the drills. The mould-board then turns them up to the surface, whence they are picked by field labourers. Another plan is for a man to dig them by means of a potato grape, and for two women to follow him to gather them up.

They are then piled either in conical pits, or in prismatic or in long ones. Upon farms the latter is usually selected. The breadth is made about seven or eight feet, and the height is about two and a half. They are then covered with dry clean straw. Earth is then dug from the ground and heaped upon the straw. It is well beaten down with the back of a spade.

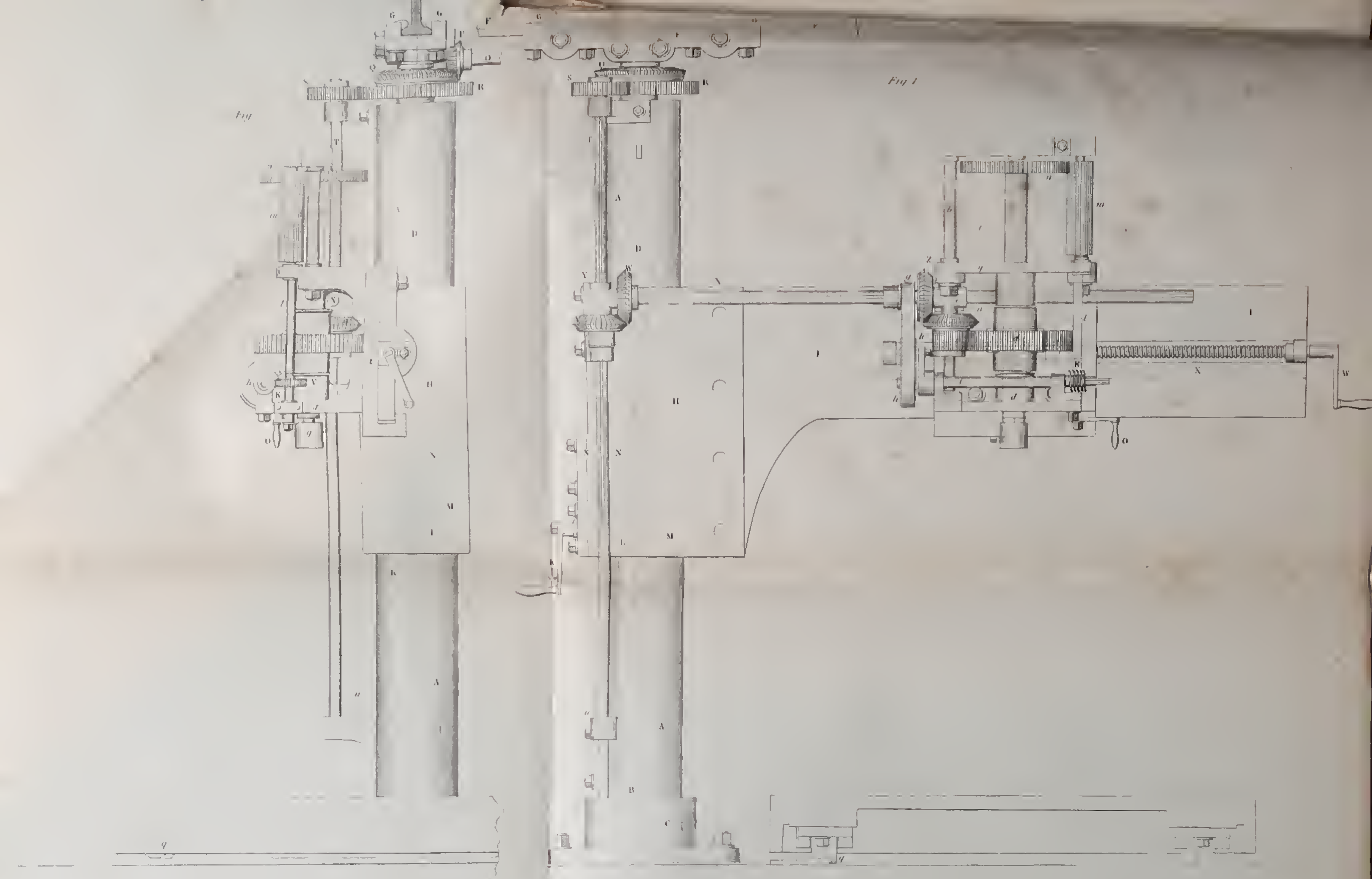
It is found that when fresh potatoes are heaped together in such large quantities, heat is apt to be generated, and the result is that the potatoes germinate. Hence it is common to leave openings or ventilators at the top of the pit, which are stopped with straw, and occasionally removed to let out the heat.

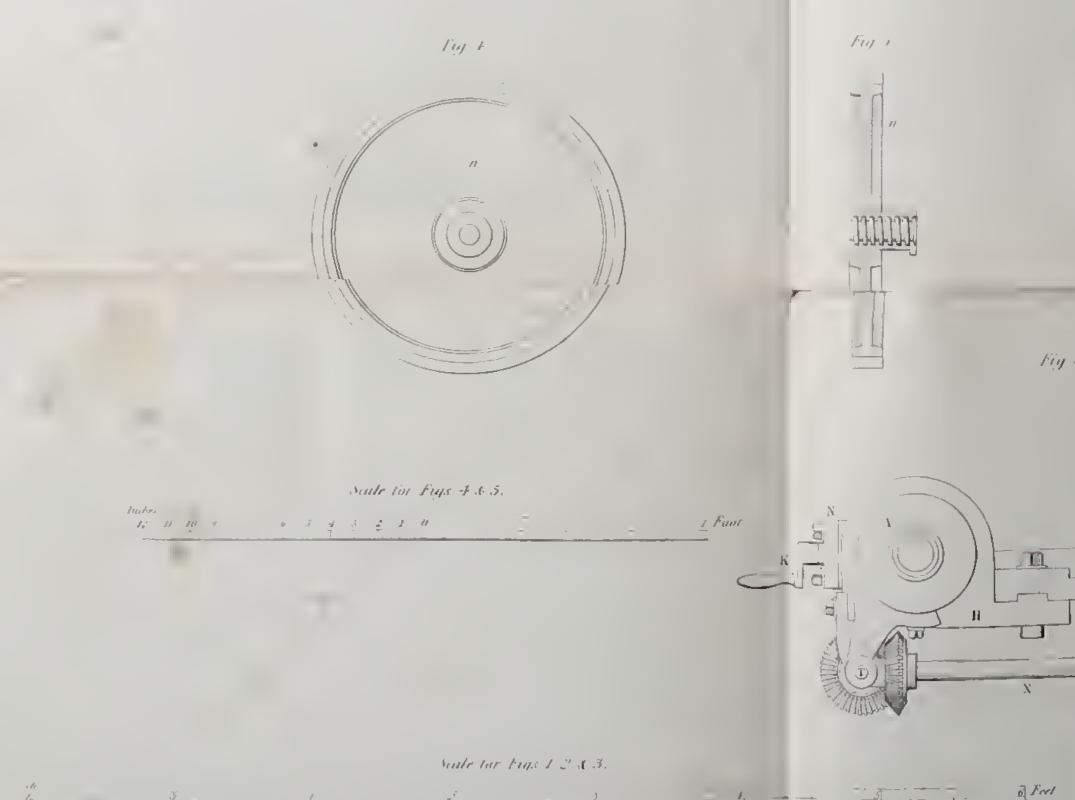
These potato stores are called pits, because the site of them really used to be below the surface. Now, however, they are almost invariably placed on the surface.

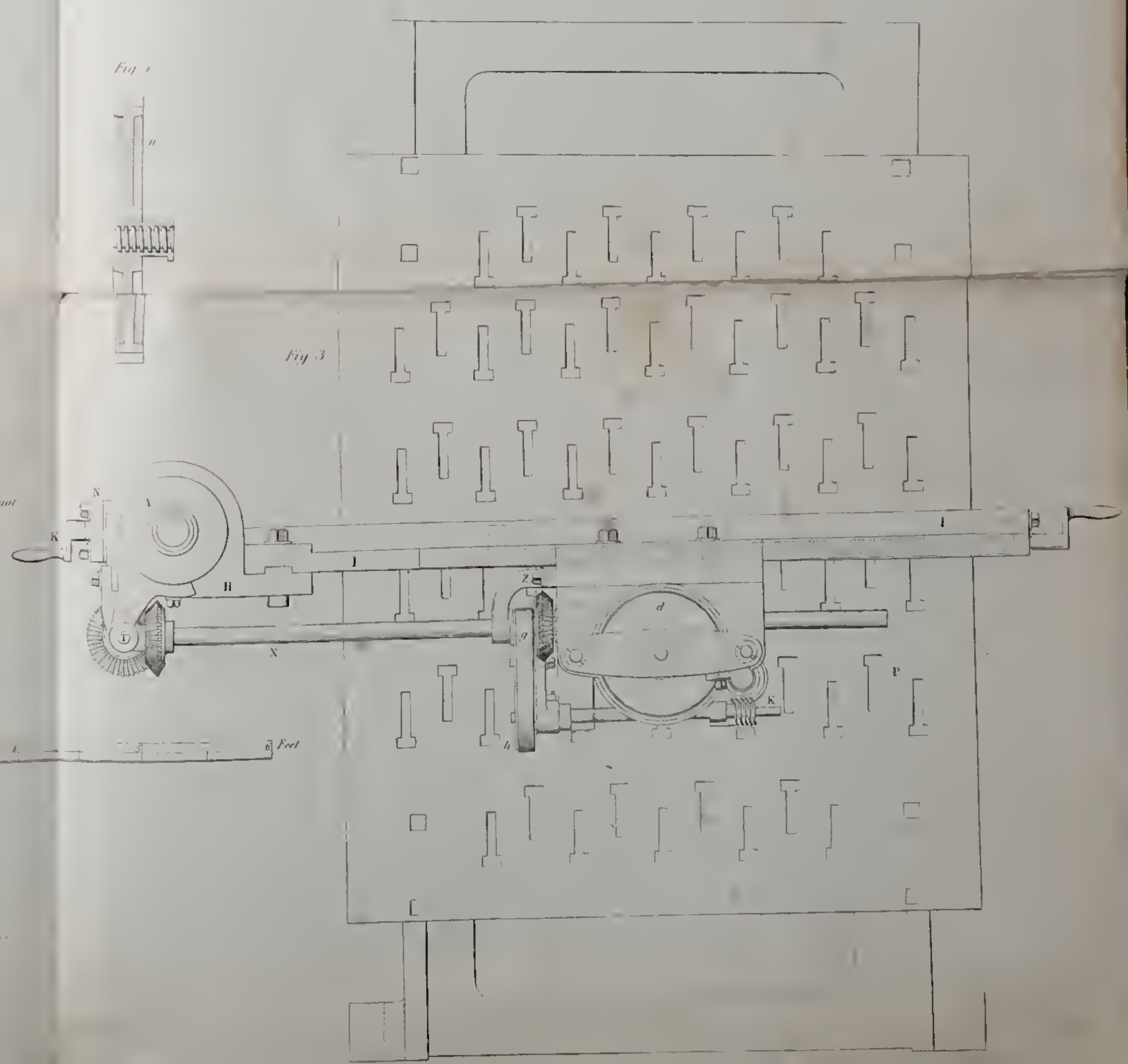
END OF VOL. II.

STEREOTYPED AND PRINTED BY WILLIAM MACKENZIE, HOWARD STREET, GLASGOW.

BUSSE'S IMPROVED IRON BRIDGE







RADIAL DRILL

BY M^r J. G. BODMER, MANCHESTER.

MINERALS.

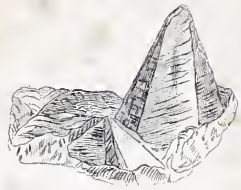
1

GOLD

2

SILVER.

3

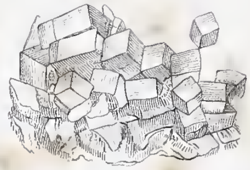


CALAMINE.

4

MALACHITE

5

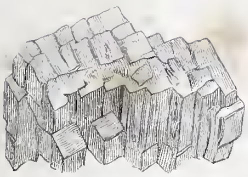


CUBIC IRON PYRITES.

6

HEMATITIC IRON ORE.

7

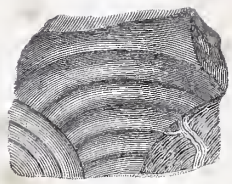


CUBIC LEAD ORE

8

BROWN PYRITES.

9

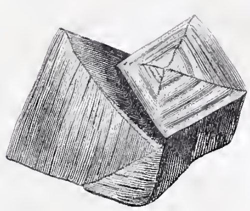


OBSIDIAN

10

GARNETS

11

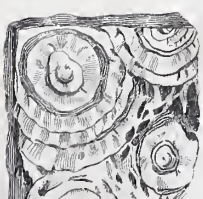


EMERALD

12

STRIPED JASPER

13

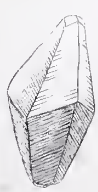


ORBICULAR GRANITE

14

BARYTES

15

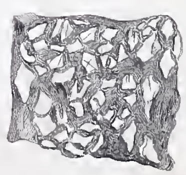


CALCAREOUS SPAR

16

GREEN LEAD ORE

17



RED PORPHYRY, WITH
WHITE FELSPAR